Bulletin 620 January 1960

UNIVERSITY OF FLORIDA
AGRICULTURAL EXPERIMENT STATIONS
J. R. BECKENBACH, Director
GAINESVILLE, FLORIDA

(A Contribution from the Citrus Experiment Station)

DEGREENING OF FLORIDA CITRUS FRUITS

W. GRIERSON, and W. F. NEWHALL

Fig. 1.—Degreening cabinets (approximately 50 cubic feet internal capacity each) used for small-scale experiments.

FOREWORD

This bulletin is intended as a presentation of what we know to date concerning degreening of citrus fruits, with particular reference to Florida conditions.

It is intended primarily for reference and for that reason has been fully indexed in order that necessary information may be readily available for readers seeking information on particular aspects.

The subject matter has been grouped so as to make available information on limited aspects (construction, effect of grove practices, etc.) to building contractors, production managers and others whose work relates indirectly to the subject of degreening, but who will not want to read an entire bulletin to obtain the limited information they need.

Experiments continue here and elsewhere and those not finding the information they need are invited to inquire at the Citrus Experiment Station, Lake Alfred, Florida. Much of the experimental work reported here has been carried out as a result of problems brought in by members of the citrus industry.

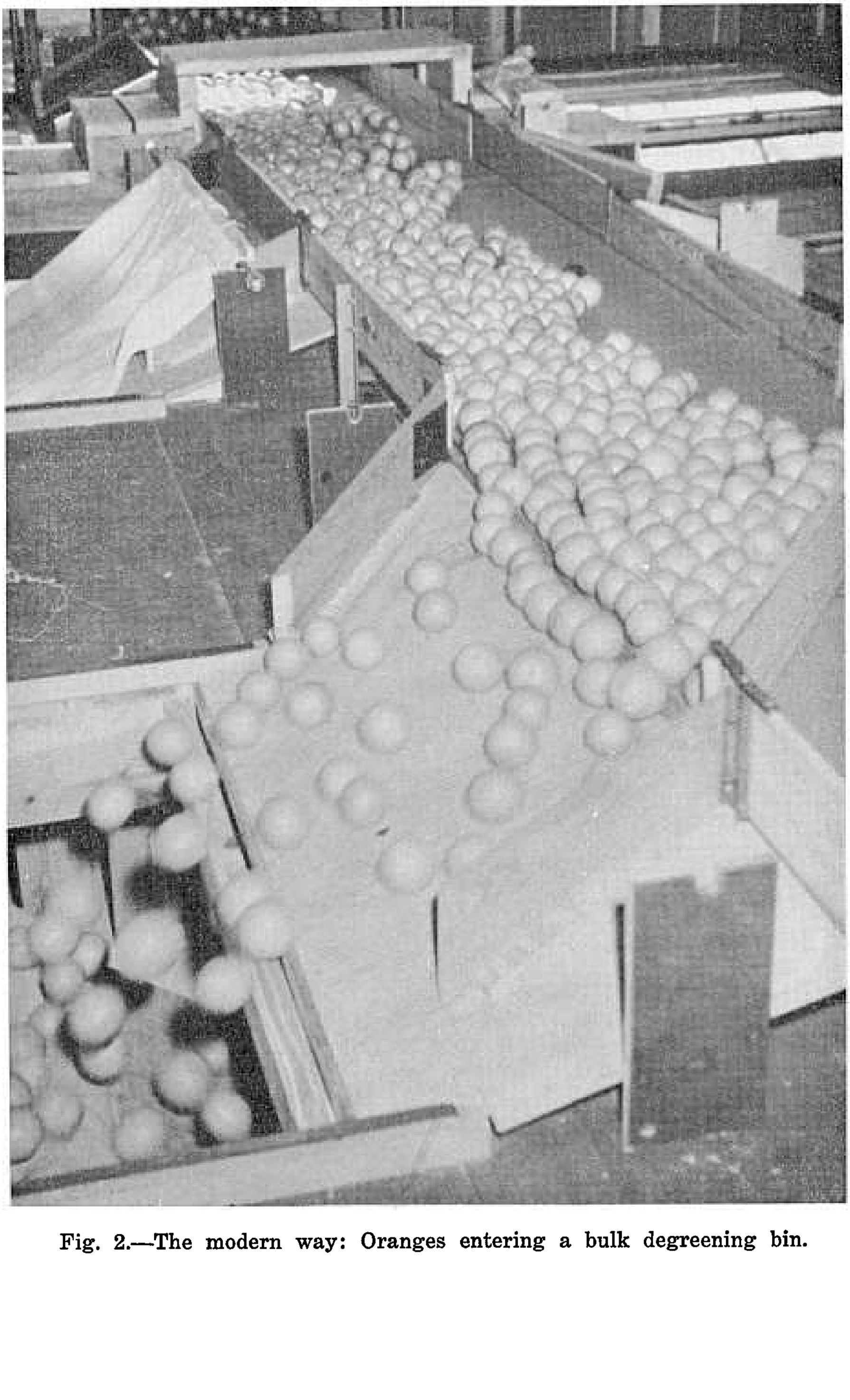

Fig. 2.—The modern way: Oranges entering a bulk degreening bin.

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Degreening of Florida Citrus Fruits

W. GRIERSON and W. F. NEWHALL [1]

INTRODUCTION

In many citrus growing districts, Florida being a notable example, external color and internal quality of the fruit may bear little relationship to each other. In the absence of cool nights, early fruits often develop good eating quality while the external color is still green.

External color of the fruit is due to the presence of the green pigment chlorophyll and various red and yellow carotenoid pigments. In the absence of chlorophyll, the carotenoid pigments control external color, which is determined by the total amounts of yellow and red carotenoids and their relative proportions.

Chlorophyll, if present, can partially or completely obscure the color due to carotenoid pigments. Even when the fruit is mature (ripe), various factors may cause chlorophyll to persist or to reappear in the peel of citrus fruits. Warm weather (particularly warm nights), high rainfall, high nutrient levels or any other conditions tending toward vigorous growth tend to cause chlorophyll to persist or reappear.

In Florida this discrepancy between exterior color and internal quality can be a considerable obstacle in marketing such early varieties as Hamlin and Parson Brown and late varieties such as Valencia and allied strains such as Lue Gim Gong and Pope Summer.

When buying oranges, grapefruit or tangerines the public inevitably associates green color with immaturity. Hence packinghouse operators choose to remove this green color by degreening with ethylene gas, thus destroying the chlorophyll in the peel without having any "ripening" effect upon the internal tissues. Ethylene degreening of citrus is therefore very different from ripening of starchy fruits such as bananas, pears or immature apples. Such ethylene treatment of citrus is variously known as "coloring," "sweating" or "degreening," according to the parlance of the citrus growing district concerned. Although "coloring" is quite commonly used in Florida, "degreening" is quite the most accurate and specific term and is favored by other research agencies such as the USDA (*67, 95, 98, 100*). Hence it is used throughout this bulletin. It is important to distin-

[1] Associate Chemist and Assistant Biochemist, respectively, Citrus Experiment Station, Lake Alfred.

guish between degreening and the "color-added" process by means of which red or orange color is added to the fruit by the use of a dye emulsion.

If correctly carried out, degreening does not harm the internal quality of the fruit which in Florida has to meet exacting legal standards (*17, 59*). Susceptibility to certain forms of decay is increased by degreening (*7, 24, 35*). Early in the season the output of Florida packinghouses is limited by 2 principal factors.

The first is the quantity of fruit that can pass the legal standards for maturity. Such standards include an initial "color break" that must be caused solely by nature, but it can usually be assumed that any fruits that pass the requirements for juice content, soluble solids and ratio of soluble solids to acid will be considered acceptable for degreening. "Spot picking" is often employed to harvest the very early fruit and Sites and Reitz (*74*) have published a detailed study of factors that can help in such spot picking for internal quality.

The second principal factor limiting output is the amount of fruit that can be put through the degreening rooms. The rate at which fruit can be put through the degreening rooms depends on the capacity of the degreening rooms and the time required to degreen. Since time to degreen fruit in an inefficient degreening room may easily be twice that taken in an efficient set-up, it is apparent that the efficiency of degreening practices materially affects the early season capacity of Florida packinghouses. The importance of this is emphasized by the fact that, particularly in houses packing a high proportion of grapefruit, the season's profits are determined very largely by the volume of fruit shipped early in the season when prices are high. This volume depends on the amount of fruit handled through the degreening rooms and the proportion of this fruit that can be packed ("percent pack-out"). Profits react very sharply to this factor of pack-out due to the fact that, particularly early in the season, packinghouse eliminations may have to be disposed of at a loss (*20, 21*). Moreover, persistent green color is an important factor in determining grade (*91, 92, 93*), and in some seasons green color accounts for the rejection of more fruit than any other grade factor (*19*).

Thus, efficiency of the degreening operation can have a major effect upon the profits in handling Florida citrus, particularly early in the shipping season.

HISTORY AND BACKGROUND

The history of degreening is very much involved with the process variously known as "curing," "sweating" or "quailing."

In the 1870's E. Bean, pioneer Florida shipper, advocated holding fruit for several days until it was slightly wilted, or to use his own phraseology (as quoted by Hume (*43*)), "until the skin was softer and more pliable." In some countries this is still the normal practice, even when no degreening is carried out, e.g., in Australia (*42*) and the West Indies (*94*). In districts where the Mediterranean fruit fly is endemic, such a curing period is commonly used to hasten the breakdown of infected fruit so they can be graded out. Hopkins and Loucks (*36*) have advocated "curing" of Florida citrus to reduce losses from blue and green molds.

Since the original purpose of this "curing" was to reduce mechanical damage by increasing the pliability of the rind, it became customary to use kerosene stoves to raise the temperature and hence hasten wilting. It was noted that this also hastened the disappearance of green color, but this was then believed to be due to the increase in temperature. In 1912 Sievers and True (*70*) reported that such degreening was not due to heat, but due to some unidentified product of the incomplete combustion of kerosene.

In 1923 Denny (*12, 13, 14*) showed that the active constituent was ethylene. No really major advance has been made since Denny's day. In fact, kerosene is still used to a surprising extent. Some excellent and progressive packinghouses claim they get better color than when using pure ethylene, particularly with tangerines. Such advances as have been made recently are either in doing a better job of air conditioning (degreening techniques are essentially a matter of air conditioning the individual fruit) or else in more efficient handling methods.

CURRENT EXPERIMENTAL WORK

The Citrus Experiment Station, Lake Alfred, conducts a continuing program of research on packinghouse methods, including degreening. Wherever possible, experimental results are quoted throughout this bulletin to illustrate points under discussion. If such results have been published, the prior source of publication is acknowledged. Results that do not carry acknowledgment of prior publication refer to hitherto unpublished findings from this Station.

Many of these experiments deal with the effect of various factors on the length of the degreening period expressed as an exact number of hours. This value is arrived at by the following method. Samples under treatment are removed from the degreening rooms and examined daily in a colorimeter essentially similar to that described by Baier and Ramsey (*1, 68*). At least 3 readings, and sometimes as many as 12, are taken on each sample and averaged. These averages are then plotted against time and, from the curve thus obtained, the time to reach an arbitrarily selected color is taken as the time to degree. These arbitrarily selected colors have the following notations on the Munsell (*52*) scale: oranges Y 8/8; tangerines YR 6/10; grapefruit gY 8/12. When repeating experiments over a considerable period, comparison of results is complicated by the fact that both degreening time and the amount of subsequent decay change considerably with the advancing season. Hence, in some experiments degreening time and decay are compared in terms of percent, with the results for a control sample degreened under standard conditions (85° F. dry bulb, 82° F. wet bulb and a constant ventilation rate determined by using a 3/64-inch ventilator setting on a 4-foot x 4-foot x 4-foot degreening cabinet such as is shown in Figure 1.

Statistical evaluation of data has been made by the methods of Snedecor (*76*).

COMPONENTS AND PROPERTIES OF THE DEGREENING ROOM ATMOSPHERE

Ethylene.—Ethylene is a gas at all temperatures above —103.9° C. It is the simplest of the chemical compounds known as unsaturated hydrocarbons, having the chemical formula of $CH_2{=}CH_2$. It occurs in minute quantities in the organic volatiles given off by most fruits. Commercially it is manufactured as a by-product of the petroleum industry. As mentioned earlier, its role in the degreening of citrus fruits was discovered in 1923 by Denny (*12, 13, 14*), who was investigating the degreening of citrus fruits by means of kerosene fumes.

Several other unsaturated gaseous hydrocarbons also act as degreening agents, although none is as effective as ethylene. Because it can be made so easily (by adding water to calcium carbide), acetylene is used in some parts of the world (*45, 79*), despite the higher concentrations necessary and the greater danger of explosion.

Ethylene exerts its physiological effects at extremely low concentrations. Concentrations as low as 1 part in 20 million (0.000,005 percent) will damage small seedling plants (*15*, *65*). Higher concentrations are used in degreening citrus, recommendations ranging from 1:50,000 (*1*, *97*) to 1:5,000 (*18*, *29*, *56*) or even as high as 1:1,000 in 1 instance (*79*). Once degreening action is initiated, increasing the concentration of ethylene does **not** speed up degreening and may cause damage to the fruit (*18*, *24*, *97*).

Unfortunately there is no rapid analytical method for ethylene suitable for use by the packinghouse operator. Hence degreening room conditions have to be set up so as to arrive at the desired ethylene concentration by "rule of thumb." As a consequence of this, it is very common for ethylene concentrations to be excessively high. In districts where stem-end rot due to *Diplodia*[2] is common, excessive amounts of ethylene greatly increase losses from stem-end rot (*4*, *6*, *7*, *18*, *24*, *44*, *97*). This is apparent from the results in Table 1, which shows the effect upon subsequent decay of various rates of ethylene delivery. In these experiments 40 cc. per hour was barely adequate for degreening and 80 cc. per hour was sufficient to give the fastest possible degreening. Hence ethylene at 120 cc. per hour approached twice the minimum concentration necessary for degreening.

Ethylene is explosive in concentrations between 3 percent and 34 percent in air (*51*). This should never need to be a hazard in the packinghouse, since the range of concentrations used for degreening lies between 0.02 percent and 0.002 percent (1:50,000 to 1:5,000). However, it is not safe to seek ethylene leaks with a lighted flame, and reasonable precautions should be taken when administering a single initial charge of ethylene instead of using the trickle system. When several cubic feet of gas are admitted into a confined space, the atmosphere in the immediate vicinity momentarily passes through the range of explosive concentration.

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[2] In Florida stem-end rot is caused by either of two organisms: *Phomopsis citri* Faw. (which is also the causal organism of melanose) and *Diplodia natalensis* Evans (which is also the causal organism of bark and wood diseases such as collar rot, root rot, twig and branch die-back). Both of these organisms are endemic in Florida groves. *Diplodia*, but not *Phomopsis*, is stimulated by ethylene (*6*, *7*, *47*).

TABLE 1.—RELATIONSHIP OF SUBSEQUENT LOSSES TO THE QUANTITY OF ETHYLENE SUPPLIED DURING DEGREENING. FROM GRIERSON AND NEWHALL (24).

Type of Fruit	No. of Expts.	Total No. of Replications	Percent Average Total Wastage at 3 Weeks from Picking — Ethylene as cc./hr. 0	40	80	120	Statistical Significance
Hamlin Oranges	2	6	26.0	27.6	33.7	36.0	*
Valencia Oranges	3	5	13.2	22.2	26.2	29.2	**
Temple Oranges	5	7	30.1	59.4	67.6	76.1	**
Tangerines	4	8	44.2	47.4	60.4	56.1	†
Duncan Grapefruit	4	10	4.6	15.7	22.7	27.5	**
Foster Pink Grapefruit	1	3	1.7	8.3	5.0	10.0	*

* Too few experiments for statistical evaluation.
** Significant at the 1 percent level.
† Significant at the 5 percent level.
("Significant at the 5 percent level" means that the odds are at least 19:1 that these differences are real. "Significant at the 1 percent level" means that the odds are at least 99:1 that these differences are real.)

Under degreening room conditions, i.e., with very low concentrations of ethylene in the atmosphere and a temperature of approximately 85° F., ethylene has very low solubility in water. This becomes of some significance in understanding the behavior of wet fruit in the degreening process.

Just how ethylene destroys the green coloring matter in the rinds of citrus is still not known. Nor, for that matter, are the many other roles played by ethylene in plant physiology understood.

Water Vapor.—Water vapor is another essential constituent of the degreening room atmosphere. The fruit is constantly giving off water vapor. If this process is not checked, the fruit rapidly shrivels and becomes unsaleable. The rate of loss of water vapor from fruit varies inversely with the relative humidity of the degreening room atmosphere. Hence the higher the humidity, the less the shrivelling that will result. At 100 percent relative humidity shrivelling ceases, but condensation starts, and wet fruit is associated with a number of degreening room troubles. A film of water on the fruit tends to slow up degreening, an effect that appears more consistently with grapefruit than with oranges.

Table 2 shows results of a number of degreening experiments using 3 different humidity levels. As has been noted before (*23*), the rate of degreening of oranges did not appear to be consistently affected by humidity levels. This is interesting in view of a California report (*1*) that their oranges fail to degreen properly at very low humidities. A more significant result of low humidity is the consequent softening of the fruit, as lack of firmness is a grade lowering factor (*92*). Rate of degreening of Duncan grapefruit was consistently and significantly slowed by excessive humidity. That wet fruit can be hard to degreen is a common observation in Florida and elsewhere (*79*).

TABLE 2.—EFFECT OF RELATIVE HUMIDITY DURING DEGREENING ON THE TIME TO DEGREEN HAMLIN ORANGES AND DUNCAN GRAPEFRUIT.

Fruit	Picking Date	Time * to Degreen (Control = 100)		
		Relative Humidity		
		Low (65-75% R.H.)	Normal (80-90% R.H.)	High (90-100% R.H.)
Hamlin	Sept. 26, 1952	97	100	100
	Oct. 1, 1952	100	100	105
	Oct. 6, 1952	104	100	103
	Sept. 28, 1953	94	100	114
	Oct. 14, 1953	110	100	110
	Oct. 19, 1953	113	100	93
	Averages	103	100	106
Differences not significant				
Duncan	Sept. 28, 1953	98	100	124
	Oct. 14, 1953	100	100	112
	Oct. 19, 1953	96	100	128
	Averages	98	100	121.3

L.S.D. (5% level) 12.3**

* Time is expressed as relative to the time taken to degreen a control sample at normal humidity.

** "L.S.D." means "least significant difference" and refers to the difference necessary before the odds are 19:1 (5 percent level) or 99:1 (1 percent level) that such differences between treatments are real.

Another trouble that is aggravated by moisture condensation is loss due to fungi (rots). Fungal losses, particularly stem-end rot, can be greatly increased by humidities high enough to cause occasional condensation. This is illustrated in Table 3, which shows the effect upon subsequent decay of various levels of relative humidity during the degreening period. It is apparent from the results shown here that excessive humidity has a much more consistent effect upon subsequent rots than it does on rate of degreening. Attention is drawn to the complex relationships between humidity, peel injury and decay as discussed in the section on "Injuries associated with degreening".

TABLE 3.—EFFECT OF RELATIVE HUMIDITY DURING DEGREENING ON SUBSEQUENT DECAY OF HAMLIN ORANGES AND DUNCAN GRAPEFRUIT.

Fruit	Picking Date (1953)	Percent Total Losses at 3 Weeks from Picking		
		Relative Humidity		
		Low (65-75% R. H.)	Medium (80-90% R. H.)	High (90-100% R. H.)
Hamlin	Sept. 28	22.0	48.7	42.0
	Oct. 14	18.7	18.0	34.7
	Oct. 19	50.0	48.7	44.0
	Averages	30.2*	38.5*	40.2*
Duncan	Sept. 28	5.3	10.7	30.7
	Oct. 14	17.3	30.7	48.0
	Oct. 19	20.0	22.7	34.7
	Averages	14.2	21.4	37.8

L.S.D.** (5% level) 7.63
(1% level) 11.96

* Differences not significant.
** See explanatory note, Table 2.

Another harmful effect of such condensation is sometimes encountered. A peculiar ring-like injury sometimes occurs at the points of contact between wet fruit (Figure 22). This is popularly attributed to ethylene dissolved in the surface water, but it is almost certainly attributable to dirt, spray residues, etc., dissolved in the water that gathers at these points. As the water evaporates, the solution ultimately can become strong enough to cause tissue injury. This action is essentially the same as "fertilizer burn" on plants.

From the foregoing it will be seen that humidity levels high enough to cause condensation during degreening are associated with slow degreening, increased decay and other troubles. On the other hand, low humidities, while checking decay, cause excessive shrinkage, shrivelling, what Rose *et al.* have termed "stem-end aging" (*66*) and other forms of peel breakdown often followed by increased decay (*41*). Thus, the humidity should be maintained as high as possible without causing condensation and its consequent problems.

Oxygen.—Since living fruit respire continually (i.e., take in oxygen and give off carbon dioxide and heat), they must have adequate oxygen if they are not to develop serious off-flavors. Also, it has been demonstrated (*14, 48*) that oxygen is necessary for the degreening action of ethylene to take place. Because of this, it is sometimes stated that oxygen levels can fall low enough in the degreening room to slow up degreening. This is most unlikely to happen, as quite elaborate measures have to be taken when lowering oxygen levels intentionally as in controlled atmosphere storage.

Carbon Dioxide.—For every volume of oxygen used by the fruit in respiration, 1 volume of carbon dioxide (CO_2) is given off. Carbon dioxide is an excellent plant narcotic and is used to arrest ripening and color change in such fruits as apples and pears and in stored cut flowers. Its action is just as marked with citrus fruits. It has been found in South Africa (*56*), California (*1*) and Florida (*18*) that as little as 1 percent of carbon dioxide almost completely arrests degreening, even in the presence of what would otherwise be an adequate concentration of ethylene.

In view of this, it becomes imperative that carbon dioxide levels be kept down during degreening. Since the fruit produces carbon dioxide continually, this can be accomplished economically only by some form of ventilation.

Organic Volatiles.—In addition to giving off carbon dioxide and water vapor, fruits of any kind also give off minute quantities of organic volatiles. Ethylene is 1 of these. But other volatile compounds also are given off, some of which account for the distinctive aroma of each kind of fruit. As well as the volatiles evolved by respiratory processes, citrus fruits give off appreciable quantities of peel oil whenever the oil glands in the rind are damaged. The effect of such volatiles on degreening is not known, but it has been shown (*36*) that peel oil atomized directly onto the fruit materially increases losses from decay. Also, peel oil destroys epidermal cells, causing "oil spotting" or oleocellosis. Experiments in which peel oil has been volatilized in the degreening chamber have not shown enough consistent increase in decay to justify attributing decay due to poor ventilation to such volatiles alone. Measures to keep down carbon dioxide in the degreening rooms will also tend to reduce the level of organic volatiles and so may serve a twofold purpose.

Nitrogen.—Seventy-five percent or more of the degreening room atmosphere is made up of nitrogen. Gaseous nitrogen is, however, completely inert and plays no part in the degreening process.

Temperature.—Temperature is of crucial importance in the degreening of citrus fruits, affecting the process in many ways. Chemical reactions are certainly involved in the destruction of chlorophyll, and in general the speed of chemical reactions increases with increasing temperature. Within plant tissues, however, a limit is soon reached as chemical reactions are controlled by enzymes, which are sensitive to temperature.

In addition to such chemical effects, the temperature acts through such physical means as affecting diffusion rate of gases, the relative humidity resulting from a given amount of water vapor in the air, etc. Nor are the effects of temperature limited to those exerted directly on the fruit. The severity of injury by various fungi causing such diseases as blue mold and stem-end rot is also directly related to temperature.

The interplay of all these factors results in an optimum temperature above or below which degreening is slowed down. This optimum tends to vary with variety, season and, most strikingly, with the particular citrus growing area. For Florida citrus it has been found to lie in the neighborhood of 85° F. (*10, 18, 23, 25*). This is considerably higher than is generally the case in other citrus growing areas throughout the world (*67, 79*). In experiments at the Citrus Experiment Station, Lake Alfred, it has been found that, in general, **raising the temperature above 85° F. slows up degreening** at least as much as does an equivalent decrease in temperature below 85° F. This is apparent in the results shown in Figure 3.

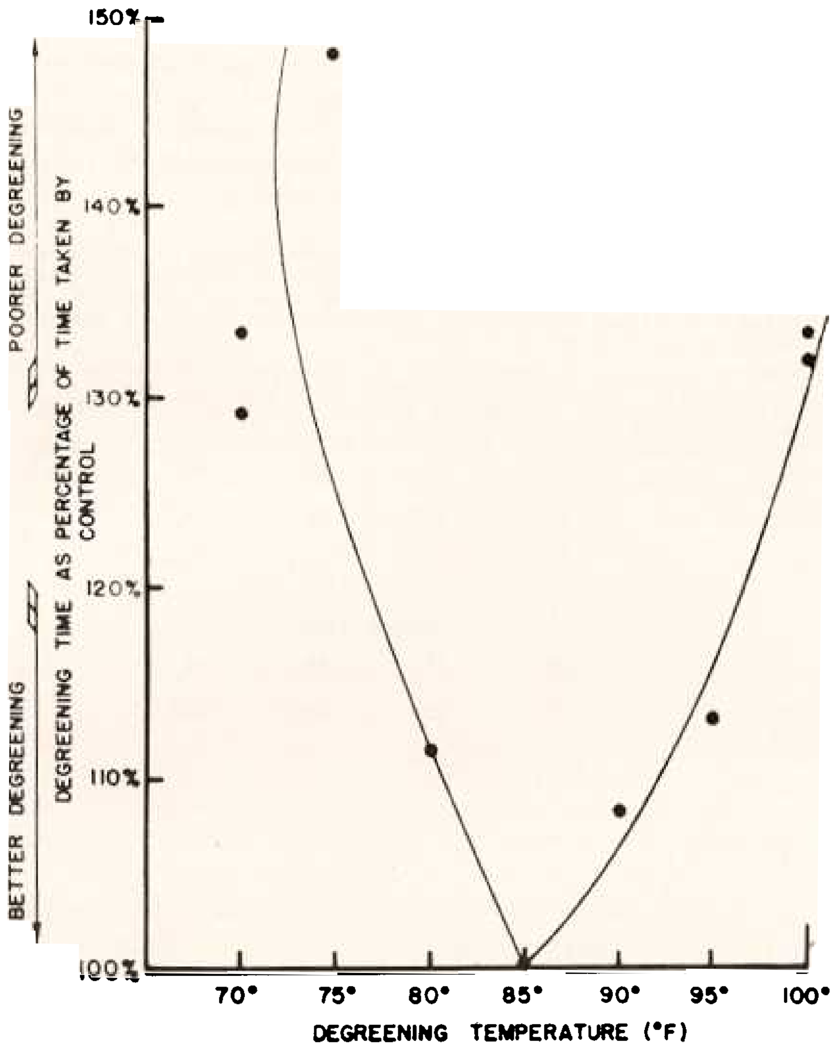


Fig. 3.—Effect of temperature on rate of degreening of Hamlin oranges. Adapted from Grierson and Newhall (*23*).

In Florida the maximum degreening temperature when heat is being applied is set by law at 85° F. (*59*). The wisdom of this ruling is shown by the data in Table 4 and Figure 3. In the experiments reported in Table 4 there is a tendency for subsequent decay to increase with increasing temperature, the effect being more marked with Marsh and Duncan grapefruit than with Hamlin oranges. In commercial practice these differences could be expected to be greater since, as is shown in Figure 3, degreening period increases with increasing temperature above 85° F. Hence, to achieve a comparable degree of color, fruit degreened at higher temperatures would have to be left in the room longer and a consequent further increase in decay could be expected. Attention is also drawn to Table 12, which shows the role of temperature as affecting so-called "gas-burn."

TABLE 4.—EFFECT OF TEMPERATURE DURING DEGREENING ON SUBSEQUENT DECAY OF ORANGES AND GRAPEFRUIT. I: HAMLIN ORANGES AND MARSH GRAPEFRUIT DEGREENED AT TEMPERATURES FROM 75° TO 90° F. II: HAMLIN ORANGES AND DUNCAN GRAPEFRUIT DEGREENED AT TEMPERATURES FROM 80° TO 91° F.

Variety	No. of Expts.	Average Percent Total Decay at 3 Weeks from Picking Date				Statistical Significance*
		I: Degreening Temperatures				
		75°	80°	85°	90°	
Hamlin	3	17.6	27.4	28.4	30.3	**
Marsh	4	18.4	21.6	23.6	27.0	†
		II: Degreening Temperatures				
		80°	85°	88°	91°	
Hamlin	7	20.8	22.0	24.1	23.2	†
Duncan	4	10.0	16.6	16.3	18.7	**

* See explanatory note Table 1.
** Significant at the 5 percent level.
† Not significant.

In citrus degreening the temperature of the rind is the only temperature exerting an effect. It is not uncommon to find operators running temperatures as high as 100° F. soon after closing the rooms "in order to get the pulp temperature up." Such a practice is not only useless, it is definitely harmful.

Air Circulation and Ventilation.—Air circulation within the rooms serves 2 principal purposes. The first is to equalize conditions throughout the room. The best indication in this regard is temperature. If the temperature is kept constant throughout the degreening rooms, it is certain that air circulation is sufficient to ensure an equitable distribution of ethylene in the atmosphere.

Related to the matter of air circulation, but nevertheless separate, is the controversial subject of ventilation. More differences of opinion exist with regard to ventilation methods than all the other aspects of degreening combined. Much of this is due to lack of comprehension as to just what ventilation seeks to accomplish. It is often said that the principal functions of ventilation are to introduce fresh air or oxygen and to lower the temperature. If either of these is needed, it is because conditions in the degreening room were faulty in the first place.

The function of ventilation is to remove the waste gases (carbon dioxide, volatiles such as peel oil vapor, etc., and possibly excess water vapor) before these can slow up degreening or stimulate decay. If this is done well enough to maintain optimum degreening, then there will always be enough fresh air or oxygen. The apparent advantages occurring from cooling during intermittent ventilation are probably due to the excellent air circulation when cold air is blown over stacks of warm fruit, an effect that is particularly marked in cold weather or when degreening temperature has been too high.

TABLE 5.—EFFECT OF VENTILATION METHOD ON RATE OF DEGREENING AND OF SUBSEQUENT DECAY OF HAMLIN ORANGES AND DUNCAN GRAPEFRUIT.

Type of Ventilation	No. of Experiments	Time to Degreen*		Decay**	
		Hamlin	Duncan	Hamlin	Duncan
None†	5	99	110	35	22
Periodic (three times daily)	8	99	99	40	31
Continuous: 1/64″	1	108	88	47	42
Continuous: 3/64″ (Control‡)	6	100	100	29	26
Continuous: 1/16″	4	119	109	25	6

* Time to degreen is expressed as a percentage of the time taken to degreen a control sample.

** Decay is expressed as average percent unmarketable fruit at three weeks from picking.

† Ventilation was actually more than "none" since samples had to be removed daily for color readings.

‡ Control sample was that using continuous ventilation at 3/64 of an inch. This refers to the setting on the ventilators of the experimental cabinets shown in Fig. 1.

Experiments at the Citrus Experiment Station have indicated that, providing carbon dioxide is kept well below 1 percent, the particular method of ventilation does not have any very consistent effect upon rate of coloring. An effect has been noted, however, on subsequent decay and is apparent in the results shown in Table 5. Possibly the increase in decay due to periodic ventilation as compared with no ventilation was due to condensation of moisture caused by the unavoidable temperature fluctuations during ventilation periods. Decay in samples subjected to various rates of continuous ventilation tends to decrease as ventilation increases. However, a practical limit is set on the amount of ventilation due to loss of ethylene. It will be noted that at the maximum rate of continuous ventilation degreening time was increased by up to 19 percent.

TYPES OF DEGREENING ROOMS

Many different types of degreening rooms exist, but they can be broadly classified according to: (1) whether air delivery is up from the floor or down from the ceiling; (2) whether solid or slatted floors are used. A further type is the bulk degreening bin in which boxes are not used. Instead, the fruit is harvested in bulk, using special equipment to minimize damage. On arrival at the packinghouse it enters the top of tall degreening bins (see Figure 2). In these bins the fruit rest on baffles of soft porous cloth while being degreened. This method is described in detail elsewhere (*55, 57*) and hence will be mentioned only briefly here.

Slatted-Floor Rooms.—Slatted-floor rooms are of 2 principal types which are usually known in Florida by the names of the companies that install them. The older type (Hale rooms, see Figures 4 and 5) have overhead fans that deliver air downward in the center of the room. The fan is above the ceiling and draws air from beneath the slatted floor through a shaft at the side of the degreening room. The space under the slatted floor is limited to the depth of the joists (about 8 inches), the joists being arranged radially, converging at the air return shaft. The theory behind this is that the space between the joists is supposed to act as return air ducts drawing air from under the whole room. This is fallacious, as the spaces between joists are tapered in the wrong direction for action as return ducts, and in practice the authors have found that nearly all the air being returned to the fan is drawn from the immediate vicinity of the return shaft. Hence air distribution in this type of room depends principally on the air from the ceiling delivery spreading over the surface of the fruit. Thus, it is advantageous to have the fruit stacked tightly to spread the incoming air over the surface of the entire load of fruit, letting it move down through the stacked fruit more due to pressure build-up than to direct blast from the fan. Small Hale-type rooms (e.g. 400 boxes) can be quite efficient. With larger rooms of this type (e.g. 1,200 boxes) real inefficiency occurs, due to the fact that the bulk of the air tends to move along the shortest possible path from the air delivery to the return duct, thus by-passing most of the fruit in the room.

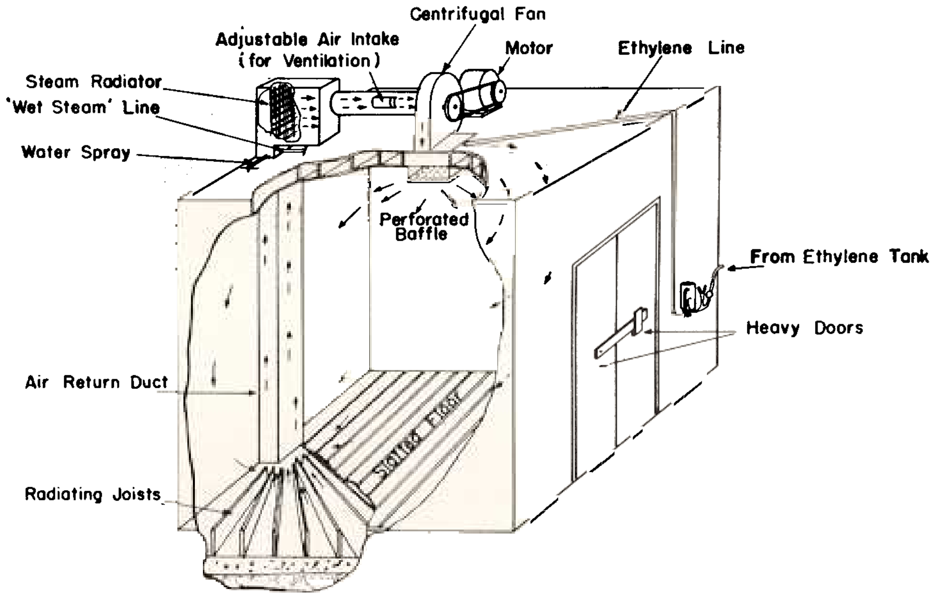


Fig. 4.—Diagrammatic representation of a Hale-type degreening room. (Note that the scale is distorted, the size of the room being small by contrast with that of the machinery.) Compare with Figure 5.

A more modern type of slatted-floor room is the type that Florida operators usually refer to as F.M.C. rooms (Figures 6 and 7). In this type of room the fan and air conditioning apparatus are below floor level. The space under the floor is usually 2 to 3 feet deep. A portable metal duct or "stack" is placed over the fan and directs the air blast against a conical deflector at ceiling level. Thus the action of the fan causes a vacuum (low pressure) area below the floor and a plenum (high pressure) area above the fruit, thereby inducing a steady air movement downward through the fruit.

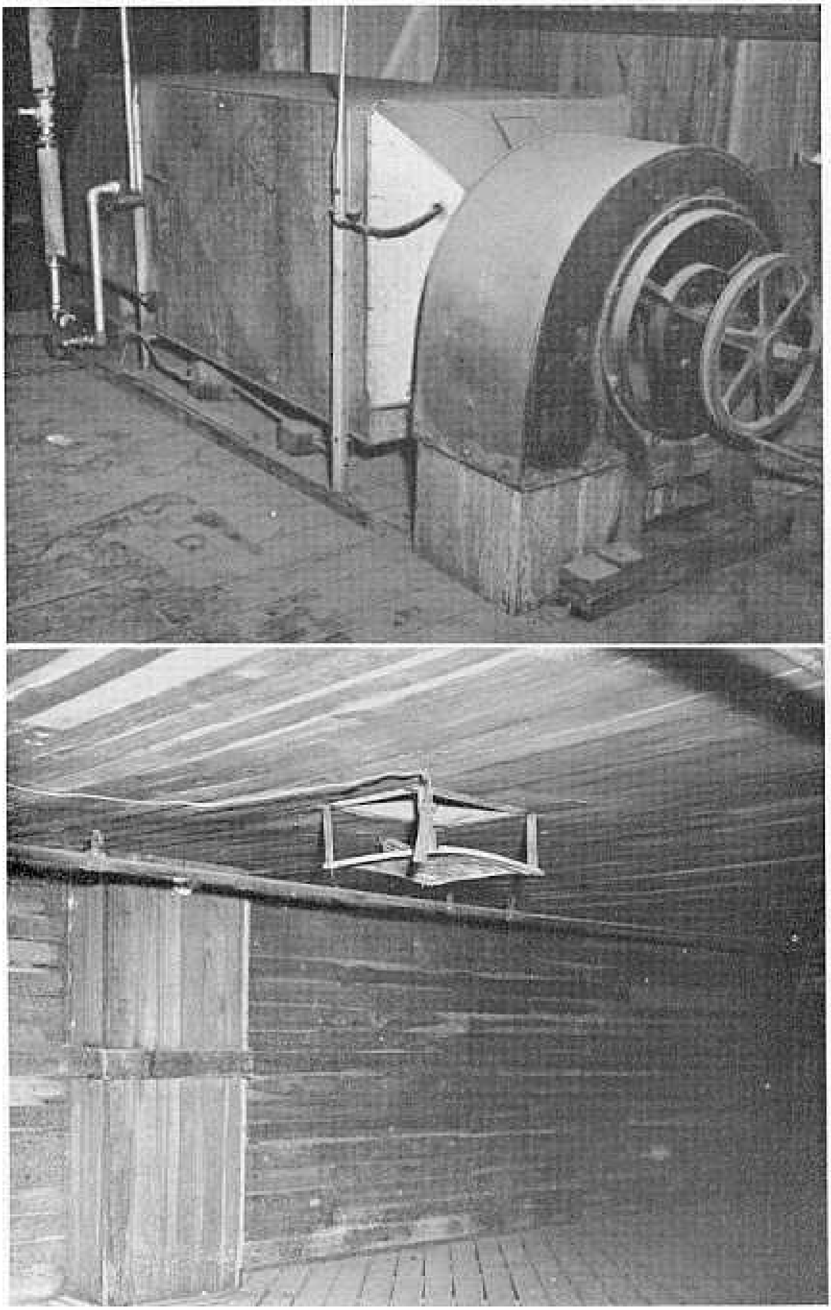


Fig. 5.—Above, machinery and below, interior of a typical Hale-type room. (Compare with diagrammatic view in Figure 4.)

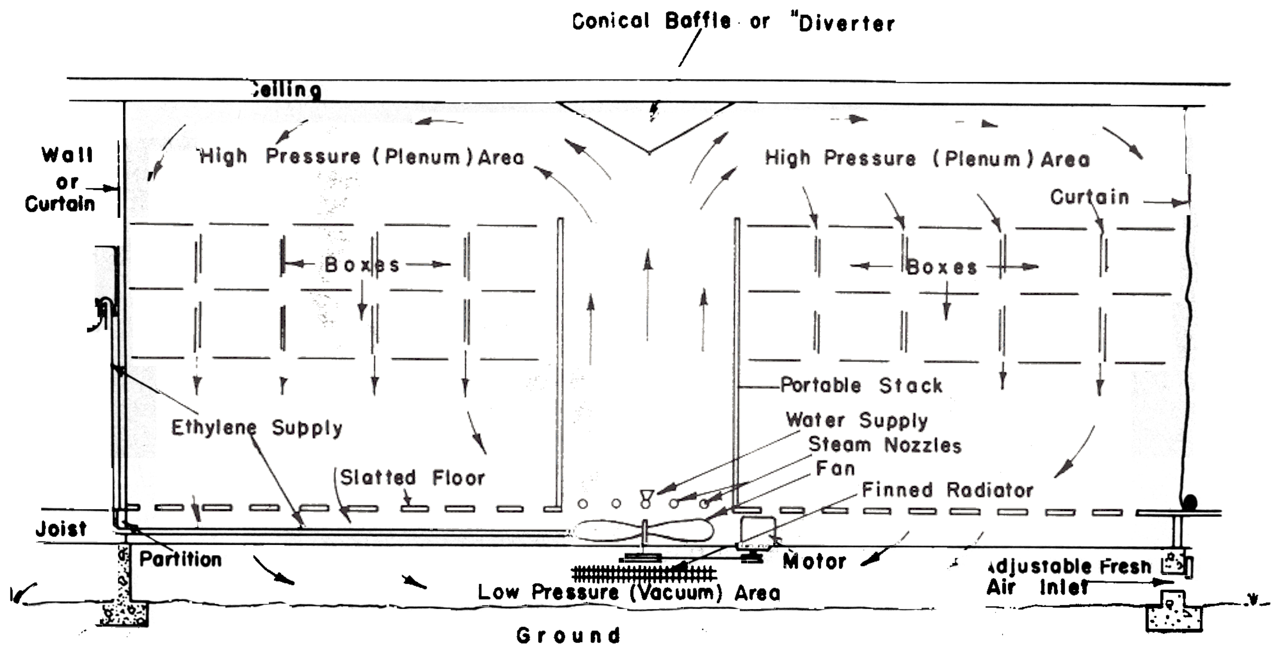


Fig. 6.—Slatted-floor degreening room. Note that the use of a slatted floor with an air space below allows for the establishment of a low pressure area under the stacks of fruit and a high pressure above, with a consequent flow of air downward through the stack. Note also that the presence of the vacuum area under the floor allows continuous ventilation by means of an adjustable opening. (Compare with Figure 7.)

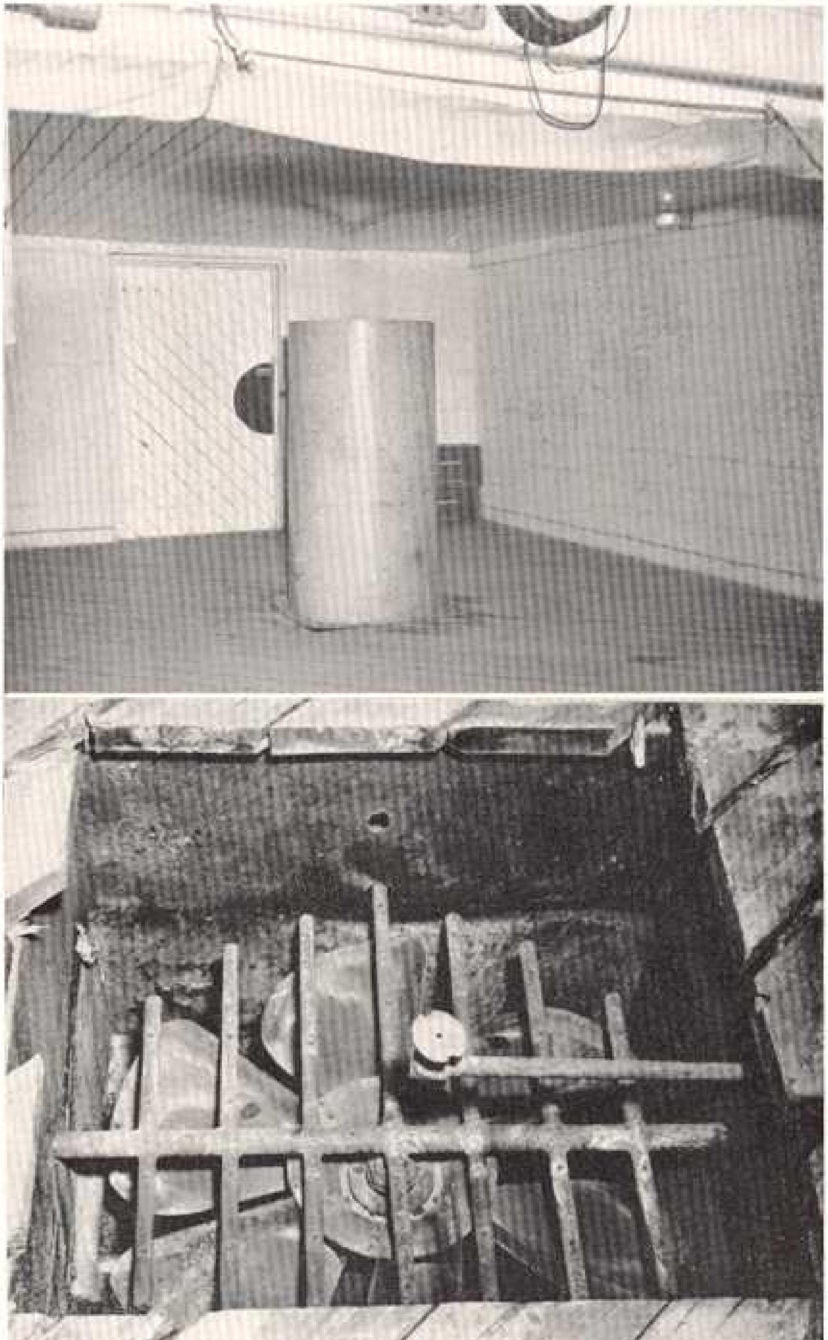


Fig. 7.—Interior of a small FMC-type degreening room, above. View of the fan, steam and water nozzles (below) visible below floor level when the stack is removed. The steam radiator is below the fan. (Compare with Figures 6 and 13.)

In small rooms (e.g. 400 boxes) a very even air distribution results. In larger rooms (e.g. 1,200 boxes) there is marked tendency for air movement to be excessive in the region of the stack and insufficient through the stacks of fruit remote from the fan. For this reason, in this type of room, the fruit should be stacked tightly, especially in the center of the room. It should not be stacked tightly against the walls, lest the air currents from the fan be deflected back toward the center of the room. This is easily demonstrated with a smoke generator such as a bee smoker.

A better device is the 1 used at Lake Alfred, a titanium tera-chloride smoke gun that generates a "cold smoke." Figure 6 shows the movement of air in this type of room.

Occasionally trouble is encountered when a single unit of this type is used in a long narrow room. Since there is very little momentum to force air toward the ends of the room, considerable inequalities in air circulation can result. Figure 8 shows 1 way of dealing with this. The simple ceiling ducts constructed of wallboard deliver air to the ends of the room.

Solid-Floor Rooms.—When solid floors are used, it is no longer possible to establish a pressure differential between the areas above and below the fruit. Hence a pressure differential has to be established on either side of the stacked fruit. Figure 9 shows how this is accomplished when a generous space is left around the walls. Air moves across the ceiling and down the walls, forming a plenum high pressure area. The fan in the central stack is drawing air from the center of the room at floor level.

In this type of room **it is clearly advantageous to have the fruit stacked with spaces between the rows and, if possible, between the stacks.** The air can then move back to the fan in the manner indicated in Figure 9. The space at the walls contributes greatly to the efficiency of this type of room. Such a space can easily be ensured by running a rail around the room about 6 or 8 inches from the wall. It is better still to use a double rail, 1 about the height of the second box and another at the height of the fourth box. This saves close supervision of truckers loading the rooms.

No matter how excellent the reasons for not doing so, there is an inevitable tendency to overload degreening rooms and the effect of this is particularly bad in solid-floor rooms. Another disadvantage of most solid floor rooms is that the permanent

center stack in the middle of the room complicates the loading and unloading of the room, particularly when using power trucks.

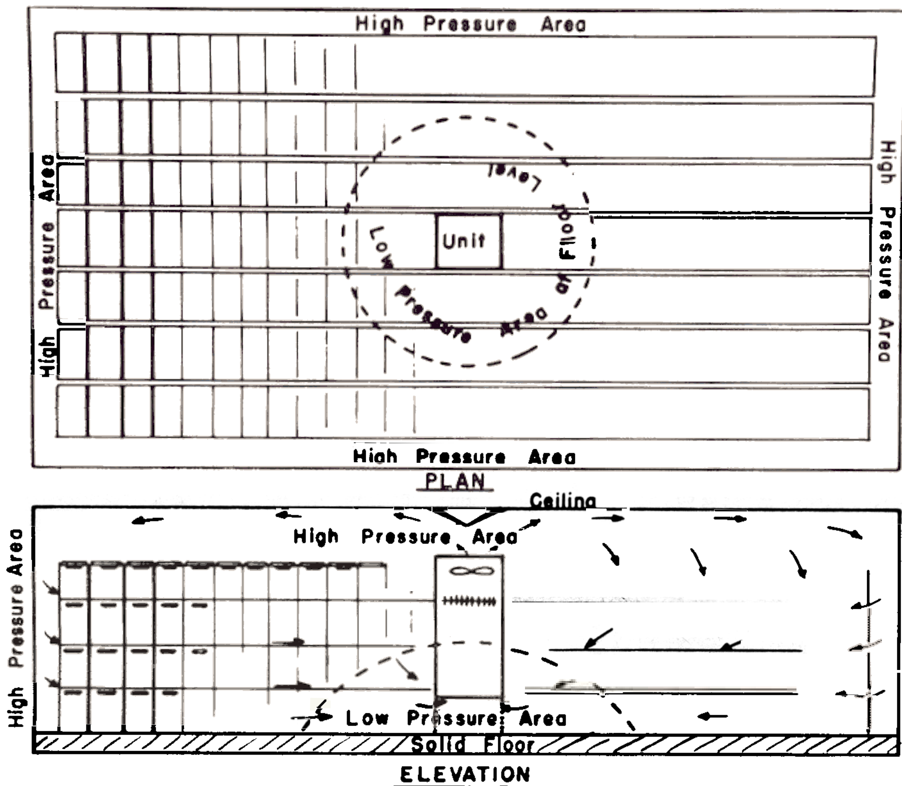


Fig. 9.—A typical solid-floor degreening room using a fixed center stack. Note how efficient air distribution depends upon leaving an adequate air space at the walls. (Compare with Figures 10 and 14.)

The authors have designed a new type of solid floor room in which overloading is of less consequence and in which the center stack is completely mobile and can be pushed into place as loading of the room progresses (Figure 10). Equally suitable is a stack with an angle iron base moved by clamp trucks. In this type of room the fan, steam heat and ethylene are all in a unit

Fig. 8.—Above: Use of simple ceiling duct to distribute air to the ends of a degreening room. Vertical 2 x 6's prevent stacking against the end walls and allow channels for good air distribution. Below: Duct encloses standard conical baffle. The space between the stack and the duct prevents backpressure developing against the fan and allows air delivery to the center of the room. The dark object in the upper right corner is the temperature-sensitive element of the automatic control on the steam line.

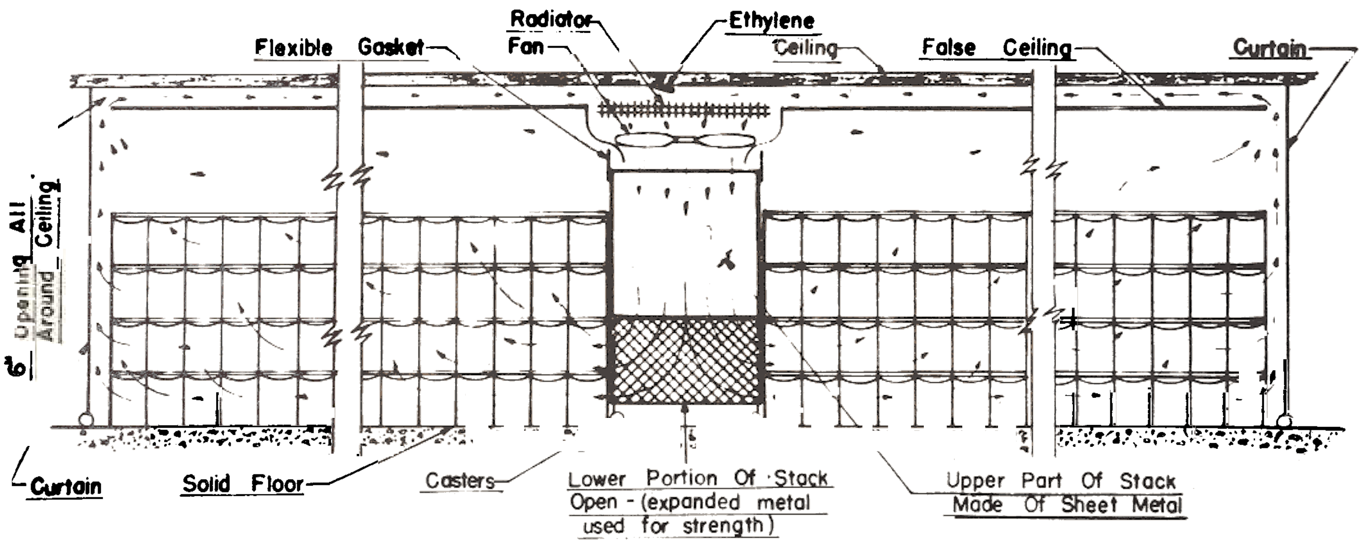


Fig. 10.—A new design for solid-floor degreening rooms. Note that all services are in the ceiling and hence the tack can be very light and portable; air is delivered into the middle of the stacked fruit; the double ceiling prevents "short circuiting" back to the fan. The thermostat is in the airstream under the fan. (Compare with Figure 9.)

in the ceiling. The fan blows downward into a portable stack with a cross-section identical with that of 2 stacks of fruit and hence fits into the loading pattern. The bottom part of the stack is open and thus the conditioned air is forced into the center of the stacked fruit. The room has a false ceiling with a narrow opening at ceiling level around the perimeter of the room; the effect of this is to force the air to pass through the stacks of fruit prior to returning to the fan. If a steam jet is to be used, it should open above the radiator and into a container with a perforated top to catch any drops of hot water. If automatic ventilation is desired, it can be provided by running an open pipe from the outside, above the false ceiling to the vacuum area immediately above the fan. The end outside the room is then equipped with an adjustable damper. A number of these rooms have been built and are performing very satisfactorily. One warning is necessary, however. Since the air passes through the fruit prior to reaching a thermometer placed in any easily accessible position, the air temperature is being checked at a point at which heat has been given up to the fruit and the air is returning to the unit for re-heating. Therefore, such rooms must be run with the apparent temperature reading about 3 degrees lower than is customary. A dry bulb temperature of 85° F. should be considered the **absolute maximum** and the sensitive unit of the thermostat should be under the fan.

This type of room is excellently suited to degreening citrus in large "pallet boxes" (*101*).

Many solid-floor rooms exist that do not correspond to any of the types described above. In very small rooms faults in circulation patterns seldom cause apparent harm. In larger rooms some of these improvised systems can prove very inefficient unless modified to give desirable air circulation patterns.

To summarize: either slatted-floor or solid-floor rooms can be very efficient, provided an intelligent effort is made to see that all fruit is situated between areas of high and low pressure with consequent systematic air movement. Slatted-floor rooms are more foolproof and usually easier to run. Solid-floor rooms need more care in stacking, but are easier to keep clean and admirably suited for power trucks. An improved design is offered for solid-floor rooms.

Bulk Bins.—The concept of degreening fruit in bulk is not new, but only within the past few years has it been practiced successfully. Bulk degreening is a necessary part of any bulk harvesting and handling operation that eliminates the use of field boxes. As a result of designs developed by the Citrus Experiment Station and the operational data obtained in cooperation with several commercial packinghouses[3], bulk degreening has now become an accepted practice in Florida. The construction of bulk degreening bins is described elsewhere (*55, 57*) and plans are available from the Citrus Experiment Station. A typical design is shown in Figures 11 and 12. Attention is also drawn to Figures 2 and 19.

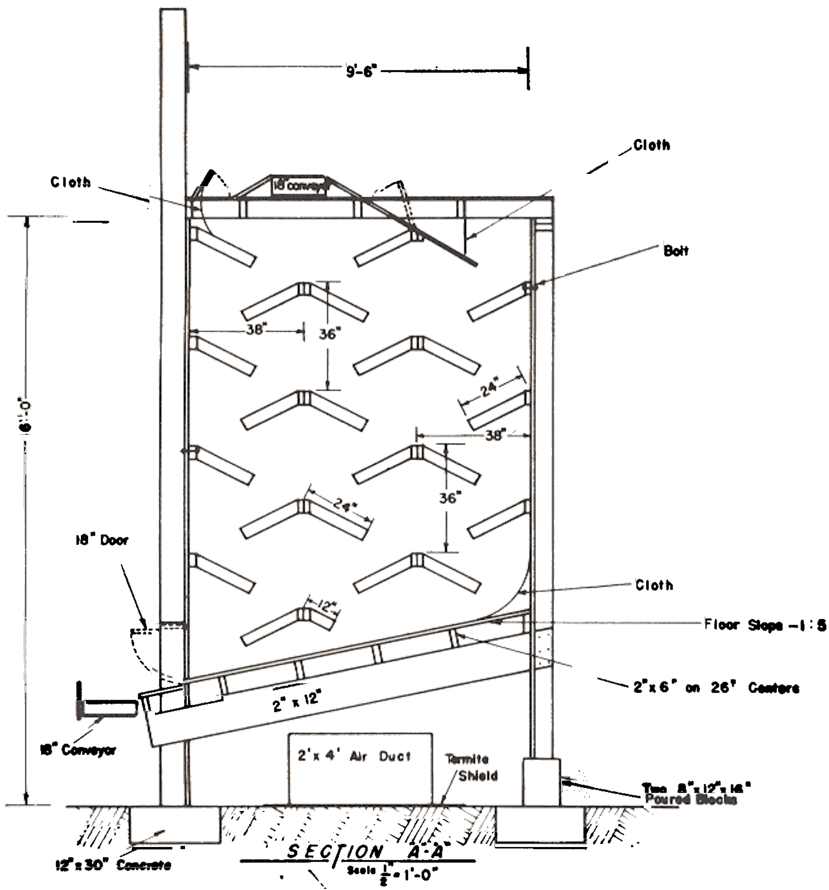


Fig. 11.—Cross-section through a typical bulk degreening bin. The cloth baffles are secured by wooden members which are shown. The cloth baffles are not shown, but are clearly visible in Figure 12.

[3] Acknowledgment is made to Haines City Citrus Growers Association, Chase and Company, and the Indian River Exchange Packers for their cooperation in experiments on bulk degreening.

Fig. 12.—Interior of a bulk degreening bin in the process of being loaded. The lowest visible baffle is full and the fruit is starting to build up on the next baffle. The cloth used is soft and porous, allowing adequate air movement through the fruit. (See also Figure 11.)

The introduction of bulk degreening has introduced a number of new possibilities, since the fruit can be given various pretreatments such as washing, pregrading, treatment with fungicides, etc., prior to degreening. This, in turn, has given rise to a number of new problems, outstanding among which is the matter of whether fruit should be washed prior to degreening.

The arguments in favor of washing prior to degreening are that (1) the bins remain much cleaner; (2) pregrading is facilitated; (3) when degreening capacity limits the amount of fruit handled, then such pregrading increases the total output of the packinghouse.

The principal argument against washing prior to degreening is that washing slows up the degreening process. When the degreening period is down to 36 hours or less, it seems likely that the advantages of washing ahead of degreening outweigh the disadvantages. For very early fruit, particularly grapefruit, the slowing of degreening due to washing can be very serious. Table 6 shows the results of a series of experiments comparing the degreening of washed and unwashed early Duncan grapefruit and Hamlin oranges. In another series of experiments prior washing slowed up degreening in 39 of 44 trials using 4 varieties of grapefruit and 2 of oranges. The average percent increases in degreening time were: Duncan 42, Marsh 23, Ruby Red 31, Foster Pink 28, Hamlin 13 and Parson Brown 17 (*27*). Why washing slows degreening is not known, but it is associated in some way with brushing. Merely dipping the fruit in water has no consistent effect upon degreening. Passage over the washer brushes (either with or without soap) causes an appreciable slowing of degreening. If grapefruit are then dried on a polisher-drier[4], a drastic increase in degreening time usually results (Table 6).

The Florida packinghouse that first adopted bulk handling combined it very successfully with pre-washing and use of the Dowicide A-hexamine fungicidal treatment (*37*, *38*), which also causes some delay in degreening of very early fruit. This packinghouse, however, is 1 that makes a principle of not picking until the natural color break is well advanced.

Waxing has an even more drastic effect in stopping degreening. Despite the fact that this was reported by Winston and Lutz as long ago as 1931 (*95*), there are still occasional attempts

[4] The term "polisher-drier" refers to a drier in which hot air is blown over the fruit as it passes over transverse horsehair, or fine nylon, brushes.

to degreen waxed fruit that has been graded out as being too green. This practice is never successful.

TABLE 6.—EFFECT OF DIPPING, WASHING AND POLISHING ON RATE OF DEGREENING OF EARLY DUNCAN GRAPEFRUIT AND HAMLIN ORANGES.

Fruit	Picking Date	Time to Degreen in Hours			Washed and Polished
		Unwashed	Dipped	Washed	
Duncan	Sept. 24, 1954	63	63	90	120
	Sept. 28, 1954	61	48	73	92
	Oct. 12, 1954	64	51	80	92
	Averages	62.7	54	81	99.3
L.S.D.*	(5% level)—18.8 (1% level)—28.6				
Hamlin	Sept. 24, 1954	105	108	113	115
	Sept. 28, 1954	81	97	97	97
	Oct. 12, 1954	92	93	102	109
	Averages	92.7	99.3	104	107
L.S.D.*	(5% level)— 8.2				
L.S.D.	(1% level)—12.2				

* (See explanatory note, Table 2.)

CONSTRUCTION OF DEGREENING ROOMS

Dimensions.—Within reason, small rooms are easier to run than big rooms. Square rooms are easier to operate than long, narrow rooms. Rooms having low ceilings are easier to run than rooms with excessively high ceilings.

On the other hand, traffic is easier to manage in larger rooms and when motor trucks are used, high ceilings are an advantage. In general, degreening rooms with capacities smaller than 400 boxes or larger than 1,000 boxes are not advantageous.

Exterior Walls.—Exterior walls should be heavy enough that temperature changes do not cause condensation on the inner surfaces of the walls and on the fruit adjacent to the walls. If existing outside walls are of poor insulating quality (as for instance when outside walls are sheet metal), a cheap and effective measure is to build an inner wall of canvas or light wallboard separated from the outer wall by approximately 4 inches of air space. Such light walls should be protected by rails or planks.

Interior Walls.—Interior walls can be of very light construction. Canvas curtains are extremely satisfactory. Such walls are sufficiently gas tight to allow the necessary concentration of ethylene to be established, and yet allow sufficient ventilation to provide against carbon dioxide build-up. Another advantage of such canvas walls is that they can be rolled up to the ceiling, allowing for free traffic movement. Figures 13 and 14 show 2 packinghouses that make excellent use of such curtains. In the example shown in Figure 13 solid walls beneath the slatted floor divide the various "rooms." The degreening units are beneath the floor. When they are not in use, the cylindrical "stacks" are replaced with metal plates and the whole area becomes available for other uses such as "set-back" space, i.e., for the assembling of various varieties, grades and sizes of packed fruit.

Fig. 13.—Canvas-walled rooms in multiple units with slatted floor. The various rooms are divided by solid walls below floor level. Above floor level all walls are canvas and can be rolled up to give a large uncluttered area that can be used for assembling packed fruit, etc. The workman is standing on the metal plate that covers a degreening unit when the central stack is not in place. (Compare with Figures 6 and 7.)

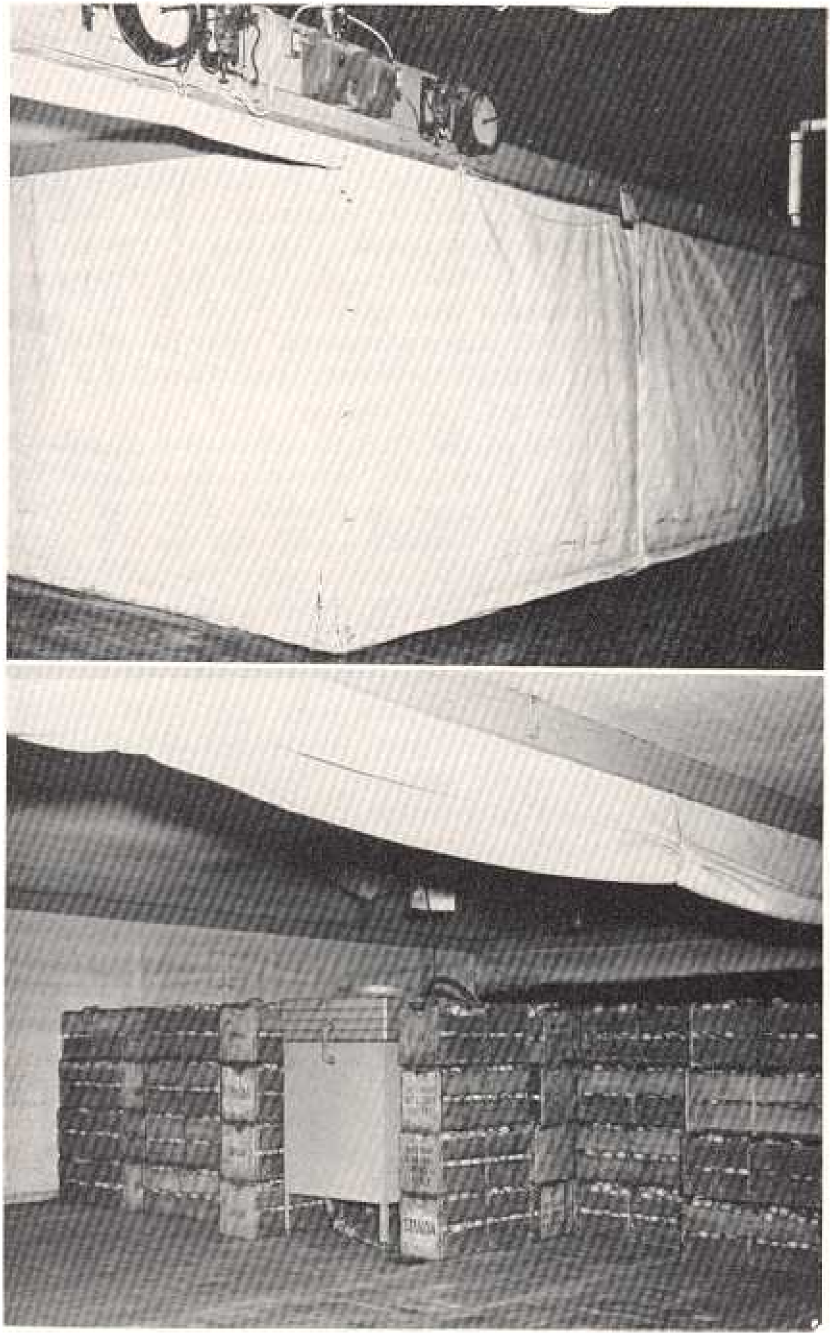


Fig. 14.—Canvas rooms with a solid ceiling, a very efficient system. Above: Note thermographs for continuous temperature recording and ethylene trickle units beside them. The interior (below) shows the central unit on wheels. It is supplied by a single steam coupling and an electric plug. The ethylene pipe delivers just below the conical baffle or "diverter". This type room is particularly well suited to the layout in Figure 10.

Figure 14 shows a similar arrangement with solid floors and portable degreening units. These are on castors and are connected by a single steam line coupling and 1 electric plug-in. Another, and even more simple, version has the heating unit attached to the ceiling and the only equipment in the portable stack is the fan. An extreme example of the use of canvas walls is shown in Figure 15. In this type of set-up the "degreening rooms" are tents suspended from the roof trusses by means of wire cable. With such an arrangement the space above the degreening room is not available for a mezzanine floor as it is with the types shown in Figures 9 and 10.

Doors.—At the time of the fruit fly infestation in 1929-30 many degreening rooms were built that were also designed for vapor-heat sterilization. During the 1956-58 infestation vapor-tight rooms were used for fumigation with ethylene dibromide. Both these types of rooms had to have very tight-fitting doors, many of which remain now that these rooms are used only for degreening. **Too tight construction accounts for more trouble in degreening rooms than any other factor encountered by these authors.** Moreover, hinged doors are necessarily limited in size, slow up traffic and invite accidents. Doorways in interior walls are far better replaced by curtains. Curtains, however, are hardly suitable for outside doorways, since in cold weather they afford little protection against heat loss and invite condensation on the fruit near the doorway. Hinge-type doors are frequently used, but have the disadvantages mentioned above. Figure 16(a) shows the use of garage-type overhead doors. These allow for wide doorways and swing out of the way when not closed. Figure 16(b) shows a very simple and inexpensive home-made garage-type door suitable for degreening rooms.

Floors.—Floors have already been discussed in the section on types of degreening rooms. Attention is drawn, however, to the problems imposed by the type of clamp trucks used, i.e., power trucks or hand trucks. Hand trucks impose little additional strain upon the floors and hence can be disregarded when selecting the type of floor. Motorized trucks are not well suited to wooden floors in general or slatted floors in particular.

In older buildings trucks may go through the floor due to unsuspected deterioration of joists or other supporting members. Other more minor difficulties are that the vibration and flexing of the floor boards tends to make the nail heads work up until

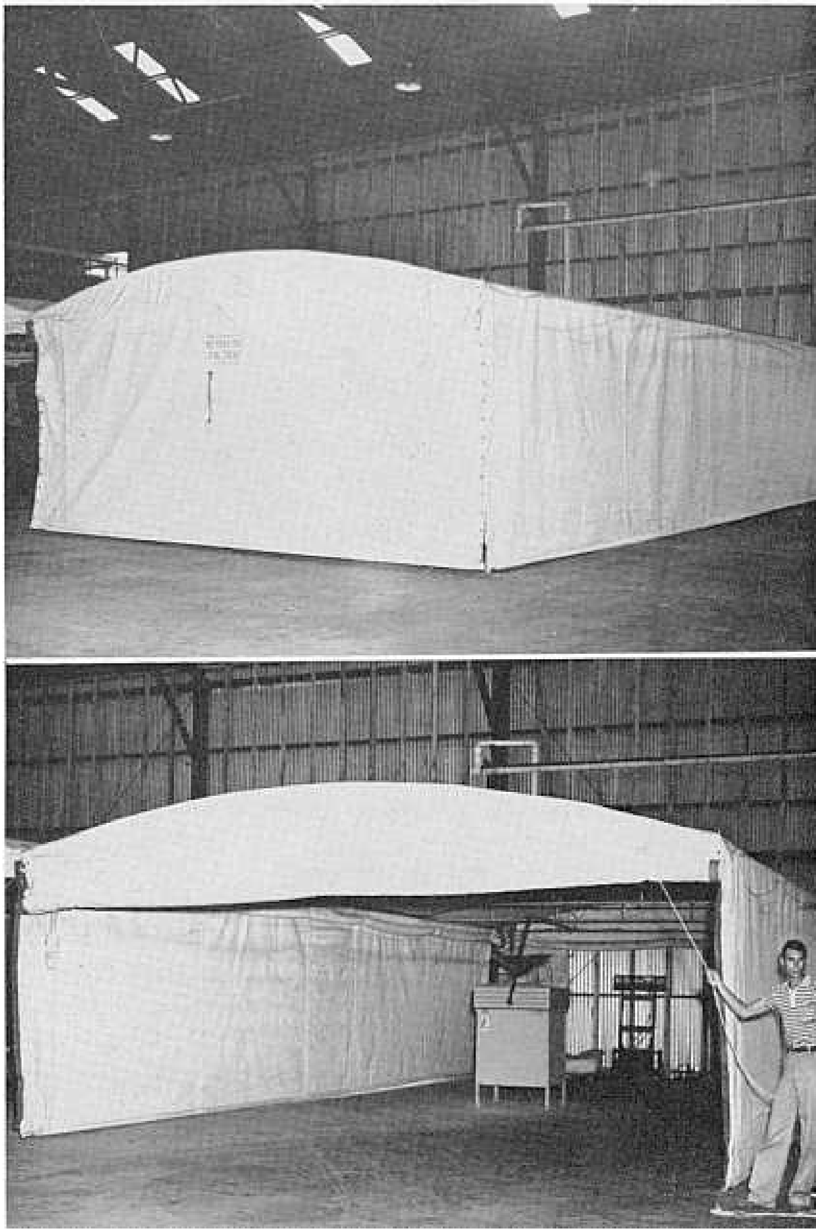


Fig. 15.—Above: Tent-type degreening room. The "tent" is suspended from the room trusses with wire cable. Below: Note that in this type of room the conical baffle is attached to the center unit.

Fig. 16.—Above: Garage-type overhead doors used on the outside walls of degreening rooms. Note (top right) that canvas curtains are used for the interior walls. Below: A very simple and inexpensive home-made version.

they catch on field boxes, cause workers to stumble, etc. Floor plates covering degreening units, floor chain motors, etc., need to be especially reinforced. If power trucks are to be introduced into old degreening rooms, such matters need to be attended to first. Power trucks are seldom fully successful on anything but concrete or other rigid floors.

OPERATION OF DEGREENING ROOMS

Ethylene.—Ethylene can be supplied either as the chemically pure gas, purchased in cylinders, or, alternatively, by the old method of using the fumes from the incomplete combustion of kerosene. This latter method has little to recommend it, although a few operators maintain that they get better results with kerosene fumes than with the bottled ethylene. It has been suggested (*97*) that this may be due to the fact that the kerosene method (whereby the fumes are blown through a duct from the "smoke house" to the degreening rooms) necessitates the introduction of considerable quantities of fresh air and hence ensures continuous and adequate ventilation.

At one time ethylene was commonly administered by the "shot method" in which a metered volume of ethylene is introduced to the degreening room at regularly spaced periods, such as every 5 or 6 hours. Today this method is seldom encountered, being very largely replaced by the "trickle" method in which ethylene is added in a continual slow stream, the gas bubbling through water, thus affording a convenient visual check on ethylene flow (*5*). Some operators use light mineral oil in their trickle units instead of water, thereby preventing the growth of molds and algae in these units.

Figure 17 illustrates a commonly used type of trickle unit. In this type the ethylene passes through a diaphragm with a pinpoint hole (or "metering orifice"). This causes a back pressure that forces up the level of the water in the manometer tube. The purpose of this device is to provide a flow meter; the flow rate is indicated by the height of the water column and interpreted by means of a graph. In actual practice this flow meter attachment is usually ignored and the rate of flow determined merely by counting the number of bubbles per minute, in which case a simple bottle and needle valve arrangement is adequate.

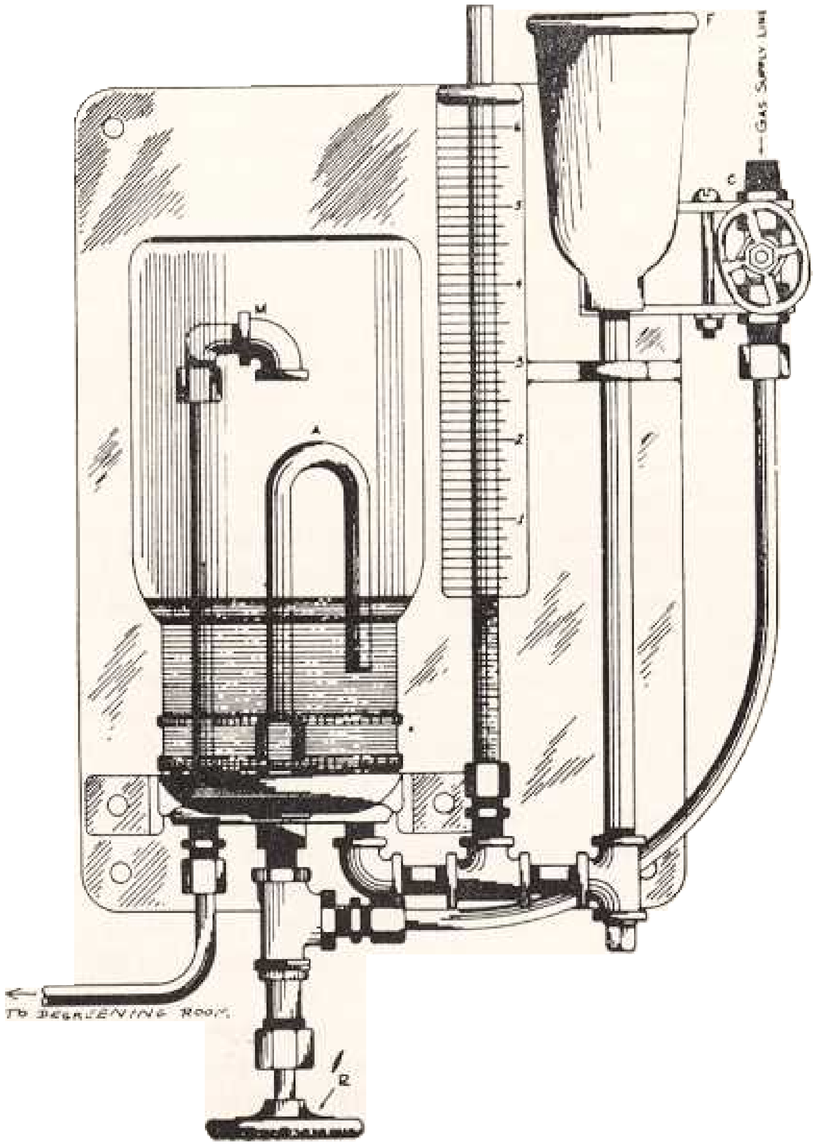


Fig. 17.—"Trickle unit" used for dispensing ethylene gas to a degreening room. Water or white oil is introduced through the funnel "F" until the level is as shown. Ethylene from the main supply line enters through the cut-off valve "C" and is regulated by the needle valve "R". The delivery pipe "A" is inverted so that the ethylene has to bubble through the water. The metering orific "M" causes a back pressure resulting in a rise in the manometer column proportional to the rate of gas flow. (Courtesy Food Machinery and Chemical Corporation.)

A simple and positive system is the use of a flow meter, of which several types are available. If a flow meter is used, useful figures to know are that 50 bubbles per minute on a typical trickle unit is approximately equal to 12 cc. per minute and that there are about 28,370 cc. in a cubic foot.

Whatever method of regulating supply is used, flow rate should be adjusted to deliver the minimum amount of ethylene that will do the job effectively. The amount will vary with the size of the room. In theory, the amount of ethylene should be varied if the room is only partially filled. However, the difference is minor and is probably best ignored.

A rough approximation is that the amount of ethylene needed will be in the neighborhood of 1 bubble per minute for each 10-box [5] capacity. In rooms with strong continuous ventilation, more may be needed. In rooms with little ventilation, or in very tightly constructed rooms, less ethylene may be needed.

The purpose in supplying ethylene is to build up a certain minimum concentration of ethylene in the atmosphere around each fruit. In practice, considerably more than the minimum amount of ethylene is usually used, on the unfortunate theory that "if a little is good, a lot must be better." Such an attitude is encouraged by the low cost of ethylene [6].

The sooner the minimum concentration (which is somewhere near 1:100,000) is reached, the sooner degreening will start. Until then the fruit is suffering the ill effects of being held in a humid atmosphere at a high temperature without benefit in the way of degreening. If gas flow is sufficient to build up this concentration rapidly, it will probably supply excessive amounts of ethylene thereafter, while slower flow rates take excessively long to build up this minimum concentration. Hence the logical procedure is to supply an initial quantity sufficient to build up the minimum concentration needed, and then have the ethylene delivery set at a rate sufficient to maintain this level. The initial amount added should be approximately 1/50 of a cubic foot for every thousand cubic foot capacity. For example: in a room 40 x 25 feet with an 8-foot ceiling and 2 feet beneath the slatted floor, total volume is 10,000 cubic feet. In such a room 1/10 of

[5] Throughout this bulletin the term "box" refers to the standard field box as defined in the Florida Citrus Code (*17*). Its internal volume is 4,800 cubic inches (2.232 U. S. bushels).

[6] Ethylene retails at approximately $30 for 25 lbs. At this rate the ethylene necessary to degreen 600 boxes for 72 hours would cost less than 25¢. Used at a rate of 60 bubbles per minute, a 25-lb. cylinder of ethylene can deliver continuously for a year.

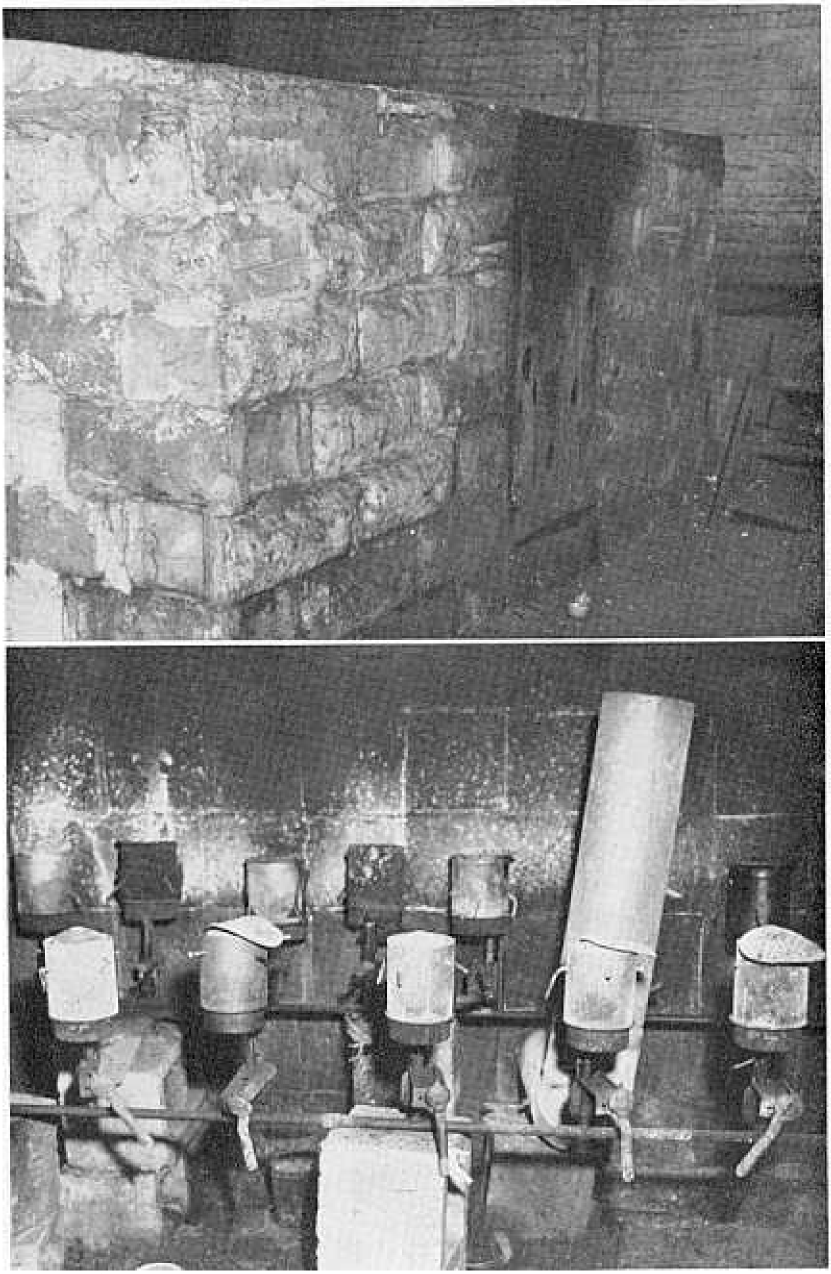


Fig. 18.—Exterior (above) and interior (below) of a masonry "smoke house" in which kerosene burners generate ethylene-rich fumes to be carried to the degreening rooms by a forced ventilation system.

a cubic foot of ethylene will raise the concentration to 1:100,000. This quantity can be measured very approximately by using the water column and chart method; e.g. consulting the manufacturer's chart for a typical unit, it would take 18 minutes at 3 inches water pressure. Using such a trickle unit, a very rough approximation is to raise the water level to 3 inches and hold it there 1 minute for each 100-box capacity. Thereafter the flow should be cut to the minimum necessary to maintain effective degreening, e.g. the 1 bubble per minute per 10-box capacity, as recommended above.

When kerosene fumes are used as the source of ethylene, Florida regulations (*59*) prescribe that the burners shall be external to, and at least 15 feet from, the coloring rooms. This requirement is fulfilled by having a stone or masonry "smoke house" in which the burners are situated. Such a structure is shown in Figure 18. A baffle over each wick assures a smokey flame with fumes rich in ethylene. These fumes are then blown through ducts to the coloring rooms by means of forced ventilation. This is why it is suggested above that some of the benefits attributed to kerosene may be due to the good ventilation inherent in this method. Although the possibility exists that there may be some other beneficial component of kerosene fumes, there is no positive evidence of this.

Humidity.—Accurate regulation of humidity is difficult; so much so that some operators do not attempt to regulate humidity during degreening.

Most degreening rooms are equipped with 6 types of controls, namely: fan; ethylene delivery; radiator ("dry steam"); steam nozzles ("wet steam"); water spray; and ventilation openings. Adjustment of any of these except ethylene delivery will affect relative humidity within the degreening room. Moreover, the harmful effects of using too low a humidity depends greatly on the amount of air circulation. The higher the rate of air circulation, the more harmful the effects of too low a humidity level. Shrivelling (and to some extent peel breakdown) is a function of both humidity and rate of air flow over the fruit.

The rooms should be run in such a manner that humidity is high enough to restrict shrivelling, but without the fruit ever becoming wet. Wet fruit should never be brought into a degreening room; but sometimes this may be unavoidable, as when trucks coming in from the grove are caught in a rain storm. When this happens the fruit should be dried as rapidly as possible. To do this the air needs to be moved rapidly, changed frequently and (if below 85° F.) heated. This is best done by loading the room, turning on the fan and radiator and leaving the ventilators and doors open until the standing water has dried off the surface of fruit.

Once the fruit is dry, the room can be closed and the ethylene turned on. To avoid the possibility of condensation, a temperature difference of about 2 to 3 degrees should be maintained between wet and dry bulb temperatures, e.g. wet bulb 82° F. and dry bulb 85° F. If the temperature spread increases beyond this, moisture should be added. If the temperature is too low, then moisture is best added by a steam jet. If the temperature is too high, then moisture should be introduced by the water spray. This also has a slight cooling action due to the absorption of heat in the evaporation of water. This cooling effect is unlikely to be more than 1 degree, F.

Any regulation of the controls will take an appreciable time to change the atmosphere in the degreening room. Hence the degreening room conditions should be rechecked a half hour or so after each adjustment.

When in doubt, it is usually better to allow the humidity to fall a little too low rather than to let it get too high with consequent risk of condensation and wet fruit. **An exception to this would be when degreening fruit known to be susceptible to peel breakdown.**

Temperature.—In hot weather fruit may come in at temperatures very much above 85° F. When this happens, it is best to air out the room after loading and, if possible, not start degreening until the fruit temperature is lower. Once the degreening room is closed, the temperature can be expected to rise to slightly above that of the temperature in the packinghouse, due to the heat of respiration of the fruit.

If the temperature is below 85° F., it is usually raised by means of the radiator (if the difference between wet and dry bulb temperatures is narrow) or the steamjet (if the wet bulb temperature is too low).

When in doubt, it is better to have the temperature a little too low, rather than a little too high. At the Citrus Experiment Station the best degreening temperature has sometimes been as low as 80° F. It has never been over 85° F. (*23*).

Early in the season a temperature as low as 85° F. is often impossible to maintain due to (1) high air temperatures; (2)

high fruit temperatures (a fact that is often overlooked is that fruit that has been exposed to the direct rays of the sun may come in at temperatures very much higher than that of the surrounding air); (3) heat of respiration. In consequence degreening rooms may go to as high as 100° F., even without added heat.

Such very high temperatures prolong the degreening period (which is already unduly long at this season) and consequently decrease the keeping quality of the fruit. Because of this it might well pay to have some of the degreening capacity refrigerated. Since packinghouses run only intermittently in the fall, for those having precooler rooms or other refrigeration it might be quite practical to devise a system whereby the compressor system could be used to cool some of the degreening rooms when such a need becomes pressing.

Efficient temperature control involves maintaining correct temperatures throughout the whole room at all levels. This in turn is quite largely dependent on efficient air circulation.

Air Circulation.—The efficiency of air circulation is largely determined by the type of room used and the equipment installed in it. Once a room is set up, comparatively little can be done to regulate air circulation without modification of the physical plant. Hence it is essential that several simple rules be followed in the installation of degreening rooms.

A common misconception is that forced air circulation necessarily involves blowing or forcing the air through the stacked fruit. It is often difficult and inefficient to blow air through a stack of fruit. On the other hand, it is easy to **draw** large volumes of air through stacked fruit by establishing slight differences in atmospheric pressure on 2 sides of the fruit. When this is done, the air moves readily through the stack in an inevitable tendency toward equalization of the pressure. For the fan or fans must tend to draw their air from one side of a stack of fruit and deliver it to another side. **Fans that merely churn up the air over the fruit are almost useless.**

Efficient air circulation involves having adequate fan capacity, but just how much fan capacity is adequate will vary with the type and size of the degreening room. One way of expressing fan capacity is in terms of cubic feet of air per minute (C.F.M.) circulated per thousand cubic feet volume within the degreening room (when empty). Efficiently functioning degreening rooms in Florida packinghouses have had between 625 and 1,500 C.F.M. per 1,000 cu. ft. air volume. Baier and Ramsey (*1*), who made a very thorough study of fan capacities for California degreening rooms, state that one 1,500 C.F.M. fan is necessary per 200 square feet of floor area. This is approximately 750 to 1,000 C.F.M. per 1,000 cu. ft. volume within the degreening room. Expressed another way, this is approximately 7.5 to 10 C.F.M. of fan capacity per 1 box capacity in the degreening room.

The USDA regulations for fruit fly fumigation rooms (*50*) stipulate fan capacity to give an air change once per minute based on the air volume of the empty room, i.e., 1,000 C.F.M. per 1,000 cubic feet capacity. (This ensures continuous circulation of the heavy ethylene dibromide vapor). When adapting existing degreening rooms to serve as fumigation chambers, this increased fan capacity considerably, resulting in a remarkable increase in efficiency when these same rooms were then used for degreening.

It must be borne in mind, however, that the harmful effects of too low humidity are exaggerated in a degreening room in which rate of air circulation is high. When air circulation is enough to ensure the maximum rate of degreening, then humidity level **must** be kept as high as possible without involving condensation.

Ventilation.—As has been mentioned already, ventilation can be either continuous or intermittent. The larger the load of fruit in relation to the air space in the degreening room, the more need for adequate ventilation.

Winston and Tilden (*97*) and Rebour (*58*) (whose account is probably largely based on Winston's reports) have advised a combination of both continuous and intermittent ventilation, but the present writers feel that in well run degreening rooms 1 method or the other should be adequate.

Continuous ventilation, although less common, is the easiest to run, and in experiments at Lake Alfred has been found to be as good as, if not better than, intermittent ventilation. In continuous ventilation an opening on the vacuum side of the fan draws in fresh air continually. Three such arrangements can be seen in Figures 4, 6 and 19. Since the total volume of air in the room has to stay approximately constant, an equivalent volume of stale air escapes from the room through any openings available. In very tightly constructed rooms (such as fruit fly fumigation rooms), it might be necessary to make a special opening, but in rooms with canvas walls or ill-fitting doors no special provision is necessary to allow for escape of stale air.

In some types of degreening rooms arrangements for continuous ventilation can be set up by running a light metal pipe from the outside to an area just behind the fan. Such a pipe or duct should be equipped with an adjustable damper. The bulk degreening system is particularly well suited to a continuous ventilation system. Figure 19 shows the simple adjustable opening for such ventilation. For any continuous ventilation system the size of the opening is dependent upon the size of the room, the load of fruit that it holds, the vacuum created by the fan and other minor factors such as the type of fruit in the room (oranges, for example, respire more rapidly and hence put out more carbon dioxide than do grapefruit).

Because of such factors the intake has to be set by trial and error for any given room. In checking rooms running successfully on the continuous ventilation system, rates of fresh air intake have been found between 1.4 percent and 3.6 percent of the total volume of the room per minute. If a velometer or anemometer is available, such a ventilation opening should be set to draw in about 2 percent of the total volume of the room per minute. Adjustment can be made thereafter to get maximum degreening rate for that particular room. Such a system is a little trouble to set up, but once in operation it runs automatically.

TABLE 7.—ADJUSTMENT OF A CONTINUAL VENTILATION OPENING ON A BULK DEGREENING BIN. SEE ALSO FIGURE 19.

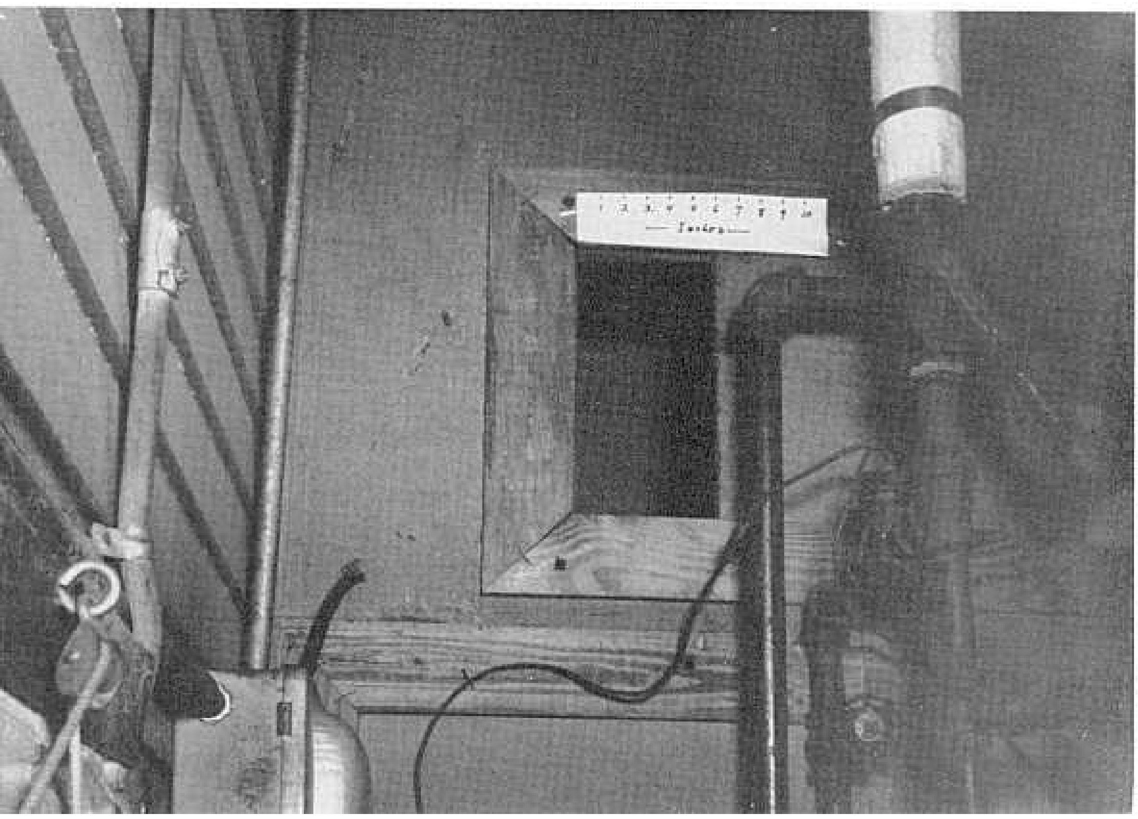
Length of Opening in Inches	Area of Opening (Square Inches)	Percent CO_2 in Degreening Atmosphere
0	0	1.0
1	6	0.9
2	12	0.85
3	18	0.8
4	24	0.45
5	30	0.25
6*	36	0.0
7	42	0.0

* Setting finally adopted.

A great deal of guess work can be eliminated by use of a simple gas analyzer of the "Orsat" type. These are inexpensive, can be operated without special training and can read carbon dioxide to 0.1 percent. Table 7 shows the readings obtained in adjusting the ventilation opening (shown in Figure 19) on a bulk degreening bin. The setting determined for 1 bin could be used on all the other bins of identical pattern. The following year, however, shrinkage of construction materials had provided enough accidental ventilation that the opening had to be reset to a smaller size.

Intermittent ventilation involves no initial experimentation to arrive at the correct setting, but makes continual demands upon labor as long as the degreening rooms are running. Methods differ widely in detail, but all involve opening the degreening room doors or curtains at intervals throughout the degreening period to ventilate the rooms. Sometimes portable fans are used to blow fresh air into the rooms. This should not be necessary for rooms of 400 boxes capacity or less, but might be advantageous in large rooms. The permanent fan or fans should be

Fig. 19.—Adjustable ventilation opening on bulk degreening bins. Three bins are operated from a single conditioning unit, so this opening supplies fresh air and reduced CO_2 level in 3 bins holding a total of about 600 boxes of fruit.



left running during the ventilation period to facilitate air exchange.

Hardening-off.—Certain crops, particularly of grapefruit, sometimes develop a form of rind breakdown known as pitting. This is aggravated by various forms of handling and can be serious enough to cause considerable concern. In order to minimize pitting of grapefruit, most operators prefer to let fruit stand for a "hardening" period after degreening and before it is run over the packinghouse machinery. With some varieties color change can be expected to go on after removal from the presence of ethylene. When this is the case, a hardening period can be given without slowing up packinghouse operations by opening up the degreening rooms before the degreening process is completed. The fruit can be either left in the degreening room or, if the degreening capacity is limited, set out on the packinghouse floor.

In experiments with Florida citrus, color change in Duncan grapefruit continued virtually uninterrupted for at least 24 hours after removal from the degreening rooms. Color change in Hamlin oranges ceased within the first 6 hours after removal from the ethylene atmosphere. Valencia oranges continued to change color for about 24 hours (see Figure 20). This is at variance with a report from California that Navels continued to color after removal from the degreening room, but Valencias did not (*1*).

Although there seems to be a fair measure of agreement among packinghouse operators with regard to the possible benefits of "hardening-off" grapefruit, the situation with regard to peel injuries of oranges is so much more complex that this is discussed in detail in the section on injuries associated with degreening. In general, "hardening off" of oranges is not advised.

CULTURAL FACTORS AFFECTING DEGREENING

This bulletin is concerned with the handling of the fruit after it has been grown. However, cultural methods have so great an effect upon degreening that they should be considered in any comprehensive discussion and no comprehensive review is known to these authors. Frequently difficulty in degreening, incorrectly attributed to inefficient packinghouse procedures, is traceable to the grove.

The effect of various grove practices upon degreening is followed closely in the packinghouse research program at the Citrus

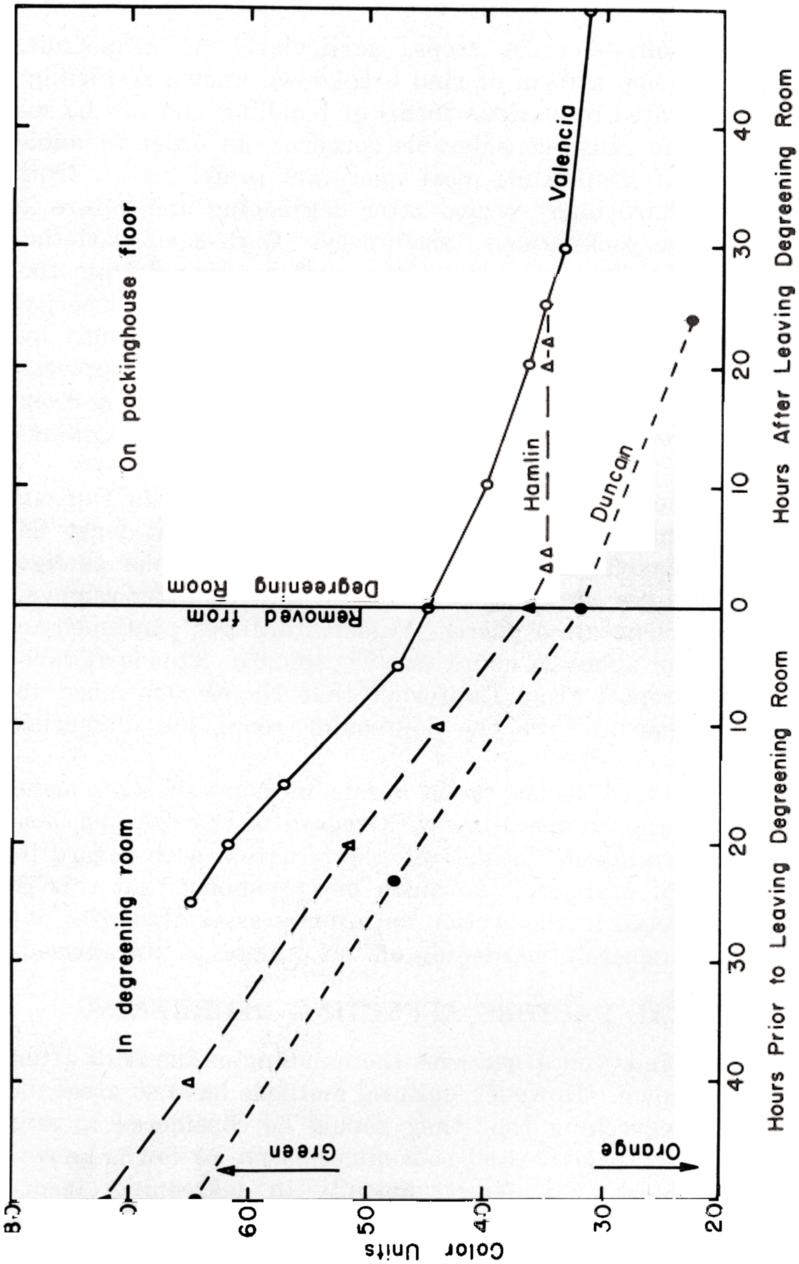


Fig. 20.—Rate of degreening of Hamlin and Valencia oranges and Duncan grapefruit before and after removal from a degreening room.

Experiment Station and certain tendencies are showing up consistently enough to merit mentioning. In addition, some information bearing on this problem has been published and reference to such literature may prove helpful.

Spray Program.—The tendency of oil sprays to delay degreening is widely known, although the seriousness of this effect is often not realized. As early as 1929 Yothers and McBride (*102*) reported that oil sprays delay the maturing of citrus fruits. Thompson (*83*, *86*) and Winston (*98*), in 1942, reported that oil sprays cause serious retardation of ethylene degreening. Sites and Thompson (*72*), in 1948, stated that, "An oil emulsion spray may have an effect on the degreening of fruit 4 or 5 months after the application if the nights are warm during October and November." They go on to say, "From the standpoint of timing oil sprays to obtain the least retarding of degreening of early varieties, the same dates should be observed as with timing the sprays to have the least effect upon solids."

With the advent of parathion, an alternative scalicide was available which had no discernible effect upon subsequent degreening. Table 8 shows data taken from a table of Thompson, Griffiths and Sites (*86*). Twelve weeks after sprays were applied, marked differences in degreening were still apparent between the oil-sprayed and the parathion-sprayed fruit. This was so marked that after 48 hours' degreening, the parathion-sprayed fruit had more than 16 times as high a percentage of well-colored fruit as did those receiving the oil spray.

TABLE 8.—DEGREENING OF EXCELSIOR GRAPEFRUIT SPRAYED JULY 15, 1951, WITH OIL AND PARATHION SPRAYS AND PICKED OCTOBER 8, 1951. FIGURES EXPRESSED IN PERCENT. (FROM DATA OF THOMPSON, GRIFFITHS AND SITES (*86*).)

Time in Degrening Room	Well Colored		Fairly Well Colored		Slightly Colored to Green	
	Oil	Parathion**	Oil	Parathion	Oil	Parathion
48 hours	4	57	71	43	25	0
65 hours	16	77	84	23	0	0
72 hours	62	97	38	3	0	0

* Oil emulsion, 1.3 percent actual oil.
** Parathion (15 percent), 1.66 lbs. per 100 gallons.

Thompson, Griffiths and Sites (*85*) and Thompson and Deszyck (*84*) investigated the effect of very small quantities of oil used in conjunction with parathion, but found that, when used in September, sprays as little as 0.4 percent actual oil delayed degreening. In 1953 Harding and Fisher (*31*) reported that not only did parathion-sprayed fruit degreen earlier than fruit sprayed with oil emulsion, but that the resultant color was a deeper, more reddish orange.

Malathion is another scalicide that does not affect subsequent degreening (*84*). In our checks of Ruby Red grapefruit from scalicide spray plots, the exterior red blush is sometimes much more pronounced in the fruit from plots that received parathion or malathion without oil.

TABLE 9.—RELATIONSHIP BETWEEN DERGEENING OF DANCY TANGERINES, DATE OF APPLICATION OF OIL SPRAY, AND PICKING DATE. (FROM W. L. THOMPSON'S SCALICIDE SPRAY PLOTS.)

Spray Date (1956)	Hours to Degreen		
	Picked* Nov. 13	Picked** Nov. 26	Picked** Dec. 10
June 15	61	32	10
June 29	63	36	14
July 17	61	38	13
August 15	72	41	12
August 31	66	49	15

* Final color on all samples tended to be dull and yellowish.
** Final color usually reddish orange.

That such effects do not always show up consistently is understandable, since the response of the fruit to degreening is affected not only by the type of scalicides used but also by the number and date of applications and the date of picking. This latter point is illustrated in Table 9, which shows the time taken to degreen tangerines from one of W. L. Thompson's oil spray timing experiments at the Citrus Experiment Station. All these tangerines were from plots sprayed with 1 percent oil emulsion, the only variable being the date of application. The samples picked November 13, 1956, showed no consistent effect of date of spray application on subsequent degreening. The samples picked November 26 showed a consistent relationship, the later the spray application the longer the fruit took to degreen. A still later picking, December 10, showed little correlation between spray date and rate of degreening, as by that time these samples needed only over-night degreening. This, incidentally, is a remarkably rapid recovery from oil sprays applied so late in the season.

The slowing up of degreening by summer oil sprays is well known, but nevertheless many early season troubles with degreening still trace back to oil sprays applied too late for subsequent early picking. Nor is this effect confined to Florida. Reports from California (*3, 54, 71, 81, 82*) state that even their very light, highly refined spray oils have been found to cause serious delay in the degreening of Valencia and Navel oranges as well as of lemons.[7] An excellent and detailed report from South Africa (*80*) states that oil sprays applied in April delayed degreening of Valencia oranges picked in September. On Navels the effect was even more marked; a **single** oil spray had a statistically significant effect in delaying degreening in 2 successive seasons.

Since summer oil sprays also delay maturity in terms of soluble solids (corresponding approximately to sugar concentration in the juice) (*34, 72, 73, 81, 82, 84, 102*), they are always risky on fruit that is to be harvested for the early market.

A minor problem in Florida, but 1 that is often erroneously attributed to degreening room conditions, is "water spotting" of Navel oranges. This is discernible at time of picking, but is seldom noticed until after degreening which, along with other packinghouse treatments, intensifies the trouble. So few Navels are grown in Florida that no systematic study of this trouble has been made here. However, reports from California (*46, 64*) indicate that not only is this trouble aggravated by oil sprays but (under California conditions) the effect can be still discernible 7 months after spraying.

Scale Insects.—Infestations of scale insects are directly related to the effectiveness of the spray program and hence have both a direct and an indirect effect upon degreening. Purple scale (*Lepidosaphes beckii* Newm.), and chaff scale (*Parlatoria pergandii* Comst.) greatly retard degreening. A single scale will arrest degreening of the rind immediately around it. A considerable scale population upon a fruit will completely stop degreening. Purple scale is readily visible and the reason for the green areas on the fruit is apparent. Chaff scale is much harder to see and often cause green spots (particularly on tangerines) sufficient to downgrade the fruit without the reason for these blemishes being readily apparent. Thompson, Pratt

[7] Ethylene degreening of Florida lemons is not advised.

and Johnson (*87*), in discussing the effect of these 2 scale insects on degreening, say, "Control measures should be taken as early as possible, especially on tangerines, because it is not known how long before harvest scale must be killed to stop their effect on degreening."

Since, as is stated above, it is well known that purple scale and chaff scale delay or arrest degreening, it is often presumed that this is true of all scale insects. The Florida red scale (*Chrysomphalus aonidum* L.) is a common pest that does not affect degreening.

Fertilization.—There is an increasing amount of evidence that the type and time of application of fertilizers can affect the degreening of citrus fruits. Most such reports deal only with color break on the tree, rather than in the degreening room, but there is no evidence that these are separate phenomena.

Reuther and Smith (*62*) report that heavy applications of potassium delay maturity of Valencia oranges both in terms of ratio and in regard to external color, the larger fruit still being green in May. The same authors (*61*) and also Winston (*99*) and Winston and Lutz (*95*) report that heavy applications of nitrogen also tend to delay color break.

Reuther and Smith (*61*) found that the effect of nitrogen upon fruit color was less than that of potassium. The effect of the 2 was accumulative, an effect that Tomkins (*88*) has reported with regard to "ratio." That this relative effect of these 2 fertilizers is not necessarily constant is shown by the results in Table 10 giving data obtained by these authors using Valencia oranges from some of the Indian River fertilizer plots of H. J. Reitz. From this table it will be seen that increasing the total amount of nitrogen sharply decreased the proportion of oranges meeting the color requirements for No. 1 grade. Ethylene degreening, although it raised the pack-out generally, did not have a great deal of effect on fruit from the high-nitrogen plots. In this experiment the effect of high potash levels was ill-defined.

Reuther and Smith (*61*) reported that Valencia oranges from high-phosphate plots "regreened" to a much greater extent than those from low-phosphate plots. This might account for the observation by these authors that in 1956-57 (a bad regreening year) color at picking and after degreening was very much better in fruit from a fertilizer experiment in which phosphorus was omitted, as compared to fruit from a treatment in which phosphorus had been used but potash was omitted.

TABLE 10.—EFFECT OF VARYING LEVELS OF NITROGEN AND POTASH ON THE COLOR OF INDIAN RIVER VALENCIA ORANGES. PICKED MARCH 1, 1957, AND DEGREENED FOR 43 HOURS. (FROM THE FERTILIZER PLOTS OF H. J. REITZ.)

Potash as Pounds of K_2O per Tree per Year	Nitrogen as Pounds N per Tree per Year					
	1.2	1.8	2.4	1.2	1.8	2.4
	Percent of Sample Meeting Color Requirement for U. S. No. 1 Grade*					
	Before Degreening			After Degreening		
0	68.8	44.9	28.0	85.1	56.3	51.0
2.4	72.0	36.0	25.0	84.0	57.4	46.9
4.8	58.8	50.0	25.5	80.4	58.8	40.4

* Each figure is the average of samples taken from 4 or more randomized plots.

In view of these findings, it is inevitable that the **total amount** of mixed fertilizers applied to the tree should affect fruit color and subsequent degreening. This has been confirmed by these authors when degreening Valencia oranges from the Indian River fertilizer plots of H. J. Reitz. A summary of the results obtained is shown in Table 11; the color of the fruit samples are indicated by the proportion of each sample meeting the requirements for No. 1 grade (*92*) both before and after degreening. This was a particularly bad year with regard to color and it will be noted that, with fruit from both the medium and high rates, color **after** degreening was worse than in the fruit from the low rate plots **prior** to degreening. Such differences could be expected to be very much less in a season such as 1957-58 when cold weather hastened color break and slowed regreening in the spring.

TABLE 11.—COLOR AT PICKING AND AFTER DEGREENING IN INDIAN RIVER VALENCIA ORANGES GROWN WITH 3 DIFFERENT LEVELS OF FERTILIZATION. PICKED MARCH 15, 1957, AND DEGREENED FOR 47 HOURS. (FROM THE FERTILIZER PLOTS OF H. J. REITZ.)

Fertilizer Application 8-4-10-7 Mix	Percent of Sample Meeting the Color Requirement for U. S. No. 1 Grade*	
	Before Degreening	After Degreening
4 lbs. per tree twice a year	63.3	86.9
13 lbs. per tree twice a year	45.4	60.1
22 lbs. per tree twice a year	41.3	59.4

* Each figure is the average of samples taken from four randomized plots.

The timing of fertilizer applications also affects degreening and other criteria of maturity. Reuther and Smith (*63*) reported on the effect of the number of fertilizer applications and the season at which they were applied. It was found that early disappearance of green color is favored by a single fall application of nitrogen rather than by applying the same total quantity of nitrogen in the form of 3 (spring, fall and winter) applications. This parallels the findings of Bahrt and Roy (*2*) and Roy (*69*), who report that when total potash requirement was applied in the fall, rather than in the customary 3 applications, legal maturity (in terms of ratio) of Parson Brown oranges was advanced by 2 to 3 weeks. They do not report on the effect upon external color or degreening, but the findings of Reuther and Smith (*63*) would indicate that these effects are related.

Reitz (*60*) reports that the color of Indian River Valencia oranges fertilized only in October was outstanding in December and January; however, during February this difference diminished so that by harvest regreening had obliterated the differences between the treatments. This affords another example of how the apparent effect of a grove treatment on color break may be affected by the date of picking. (Compare with the results of oil sprays on tangerines as shown in Table 9.)

Martin (*49*), reporting on Marsh grapefruit grown in Arizona, found that color break was accelerated by a low nitrogen content of the tissues of the tree, regardless of whether this effect was due to reduced fertilization, application of nitrogen in winter rather than in spring or summer or competition for nitrogen by summer cover crops.

Trace Element Nutrition.—In the course of checking several hundred fruit samples from trace element experiments,[8] no consistent effect on fruit color or degreening has been discerned.

Irrigation.—In reviewing the above papers and experiments on sprays and fertilizers, it is apparent that those factors that tend to delay degreening are the same factors that tend to delay maturity in terms of other standards such as ratio and solids. This affords some degree of confirmation of the observation commonly made by packinghouse operators that "high-solids crops degreen easier than low-solids crops." With irrigation no such clear-cut relationship is apparent and hence the problem has to be approached with particular caution.

[8] Acknowledgment is made to Drs. H. J. Reitz, E. J. Deszyck and J. T. Griffiths, from whose experiments these samples have been obtained.

One of the most difficult problems in early season degreening is associated with handling a crop set from a scattered or irregular bloom period. The authors have seen such a crop of Parson Brown oranges picked in the first week of November pack out as low as 20 percent due to failure to degreen properly. Such a low pack-out with very early season fruit is particularly costly due to the poor market for packinghouse eliminations at that season (*21*). Sites, Reitz and Deszyck (*75*) report that, in experiments with Marsh and Silver Cluster grapefruit, late or scattered bloom could be controlled to some extent by judicious irrigation. Thullberry (*89*), writing some 6 years later, stated that growers wishing to raise an early crop of grapefruit sometimes start irrigation in December to force an early bloom. As Turnbull (*90*) has pointed out, such a practice is hazardous in the event of a severe freeze.

Other Factors Affecting Degreening.—Other factors affecting color break and degreening include some that are not readily controlled by the grower. Despite the numerous publications dealing with the effect of rootstocks upon other aspects of fruit quality, there is very little known of their effect upon color and color break. Studies such as those of Harding (*30, 31, 32, 33*) indicate that rootstock influences follow the general tendency for vigorous vegetative growth (such as is characteristic of rough lemon stock) to be associated with delayed color break and slow degreening. This observation appears to be confirmed by observations made on the samples from various rootstocks examined periodically in the Citrus Station packinghouse.

Climate and seasonal differences have well defined effects upon color break and degreening. Stearns (*77*) and Stearns and Young (*78*) carried out very careful studies of the relationship between climatic conditions and color break. With Hamlin, Parson Brown and Pineapple oranges they found that there was no consistent color break until minimum temperatures dropped below 55° F. and thereafter the extent of color break was related to the duration and severity of the periods when minimum temperatures were below 55° F. They also reported that the duration of ethylene degreening necessary to degreen oranges was related to previous climatic conditions, **even when considering oranges having the same degree of green color.**

These same authors also investigated color break in Marsh and Duncan grapefruit but could find no such correlation with climatic conditions as they found with oranges. Color break tended to be gradual and fairly consistent throughout the fall and early winter. Caprio (*8, 9*), reporting on a 28-year study of regreening of California Valencia oranges, states that serious regreening was related to delayed blooming date, immaturity at onset of winter and warm weather in the several months prior to harvest.

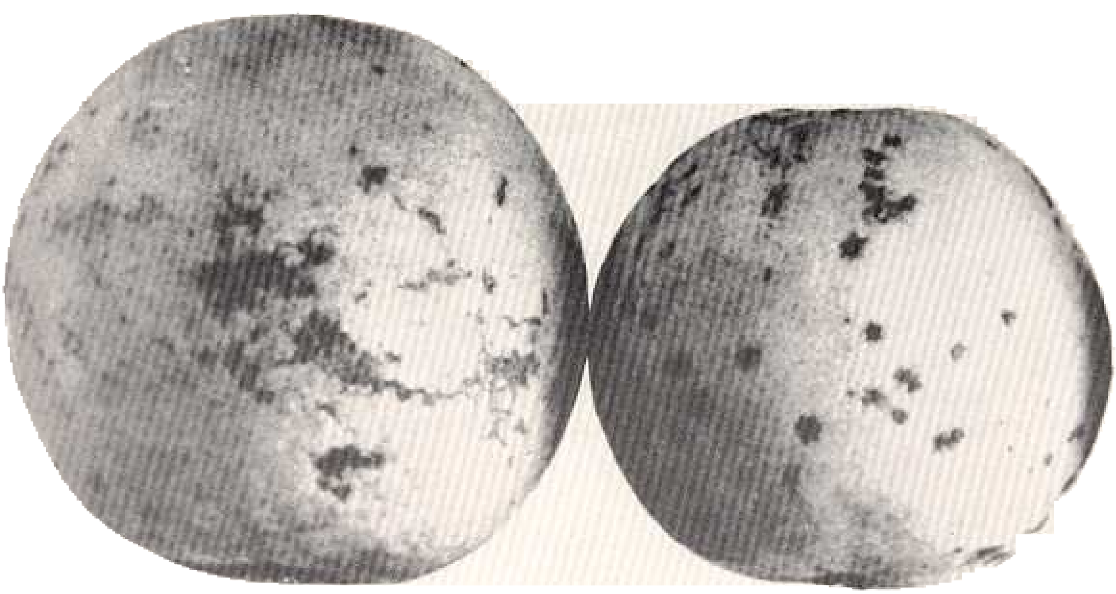
Arsenic sprays are often erroneously credited with affecting degreening. Since these are used to hasten maturity of grapefruit, it is sometimes assumed that they must have an effect upon color break. Experiments at the Citrus Experiment Station (*16*) indicate that arsenic sprays have no consistent effect on subsequent degreening. This confirms Juritz' (*44*) observation that arsenical sprays did not affect external appearance of South African oranges.

INJURIES ASSOCIATED WITH DEGREENING

Discussion of degreening methods throughout this bulletin has of necessity involved the mention of the various injuries and diseases that are associated, one way or another, with degreening. However, these troubles are often the cause of much controversy, much of which is due to imperfect understanding of factors that cause them.

"Gas Burn" or "Ethylene Burn" of Oranges and Grapefruit.— Several distinct types of epidermal injury are commonly included in the terms "gas burn" or "ethylene burn." The commonest

Fig. 21.—So called "gas burn" on early season Hamlin oranges. The lesions are usually brown and slightly sunken.



2 are a brown spotting that may appear as either scattered pits or else as widespread, slightly sunken discolored areas (Figure 21) and "ring burns" which are discolored circular injuries that sometimes occur at the points of contact between the individual fruits (Figure 22).

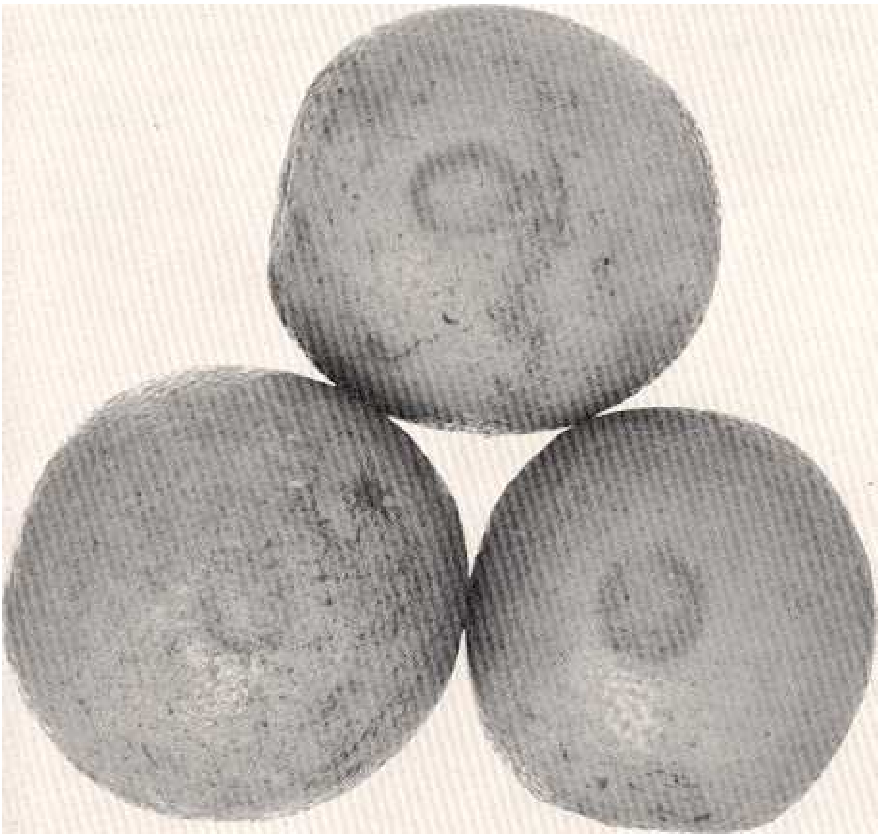


Fig. 22.- "Ring burns." Note the circular discoloration formed where fruit have been in contact with one another.

On oranges and grapefruit such blemishes are seldom, if ever, initiated by ethylene, although it may be a contributing factor. Very definite ethylene injury has, however, been found on Temples (22) and, to a lesser extent, tangerines (*24*).

Rose *et al* (*66*) state categorically that such injuries are due to degreening room conditions other than ethylene. Later research (*22*. *24*) would indicate that this statement is still true, with certain reservations. They attribute such so-called "gas-burn" to low humidity in the degreening room. Table 12 shows the "gas burn" found in a series of experiments with immature Hamlins. The fruit shown in Figure 21 are from this same experiment. The amount of this injury was related to degreening temperature and to picking date. Raising the temperature from 85° F. to 100° F. caused approximately 1,000 percent increase in the amount of "gas burn." Comparing the samples degreened

TABLE 12.—RELATIONSHIP OF PICKING DATE, RELATIVE HUMIDITY, DEGREENING TEMPERATURE, AND LENGTH OF DEGREENING PERIOD TO OCCURRENCE OF "GAS BURN" OF HAMLIN ORANGES.

Picking Date	Relative Humidity*	Temperature °F.	Percent Peel Injury	Hours to Degreen**
September 26, 1952	Low	85	4.0	67
	Normal	85	4.8	68
	High	85	5.2	74
October 1, 1952	Low	100	50.8	95
	Normal	100	57.0	95
	High	100	42.0	96
	Normal	85	2.0	72
October 6, 1952	Low	70	0	88
	Normal	70	0	85
	High	70	0	85
	Normal	85	0	66
October 13, 1952	Normal	75	0	63
	Normal	85	0	42.5
	Normal	95	0	48
October 16, 1952	Normal	80	0	45.5
	Normal	85	0	41
	Normal	90	0	42

* Low—60-70 percent; Normal—80-90 percent; High—90 percent and up.

** All degreened to the same color as judged with a visual comparison colorimeter. (40 percent green = Munsell g Y 8/10 (*52*).

All samples received ethylene and at the same rate.

at 85° F. and normal humidity (which was used as the control treatment for all picks), the amount of "gas burn" decreased as the fruit approached maturity, dropping from 4.8 percent for the September 26 picking to zero for the October 6 picking. No correlation was found with humidity. (But note that other types of peel injury on oranges, as discussed below, are closely related to humidity.)

Table 13 shows results from another experiment in which washed and unwashed fruit were held in the degreening cabinets with and without ethylene. In this experiment, which was with immature fruit also, the most serious amounts of this so-called "gas burn" occurred with unwashed fruit. In another experiment washing prior to degreening reduced "gas burn" of Hamlin oranges from 17 percent to 1 percent and from 18 percent to zero for Navel oranges.

TABLE 13.—EFFECT OF WASHING, PICKING DATE AND ETHYLENE ON OCCURRENCE OF "GAS BURN" ON HAMLIN ORANGES AND DUNCAN GRAPEFRUIT.

Treatment	Picking Date (1954)	Percentage of Fruits Injured			
		Hamlin Oranges		Duncan Grapefruit	
		With Ethylene	No Ethylene	With Ethylene	No Ethylene
Washed	Sept. 13	2	0	0	0
	Sept. 16	0	0	8	0
	Sept. 24	0	0	0	0
	Averages	0.7	0	2.7	0
Unwashed	Sept. 13	25	18	0	0
	Sept. 16	25	0	2	0
	Sept. 24	0	0	0	0
	Averages	16.7	6	0.7	0

Hence it would appear that much of this so-called "gas burn" is due to the "burning" action of dirt, fertilizer dust, spray residues, etc., which dissolve in water on the surface of the fruit, and resultant solution gradually grows more concentrated as it evaporates. This would agree with the observation by Stevenson (*79*) that spray residues on Australian citrus commonly cause "blotching" during degreening. Either this is not the sole cause, or else it is indistinguishable from some less common injury since, although this injury can occur in the absence of ethylene, ethylene often increases its severity. This is apparent in the data presented in Table 13. Moreover, as in Table 13, in these experiments occasional apparent "gas burn" is encountered on washed fruit, indicating that dirt is not the sole cause.

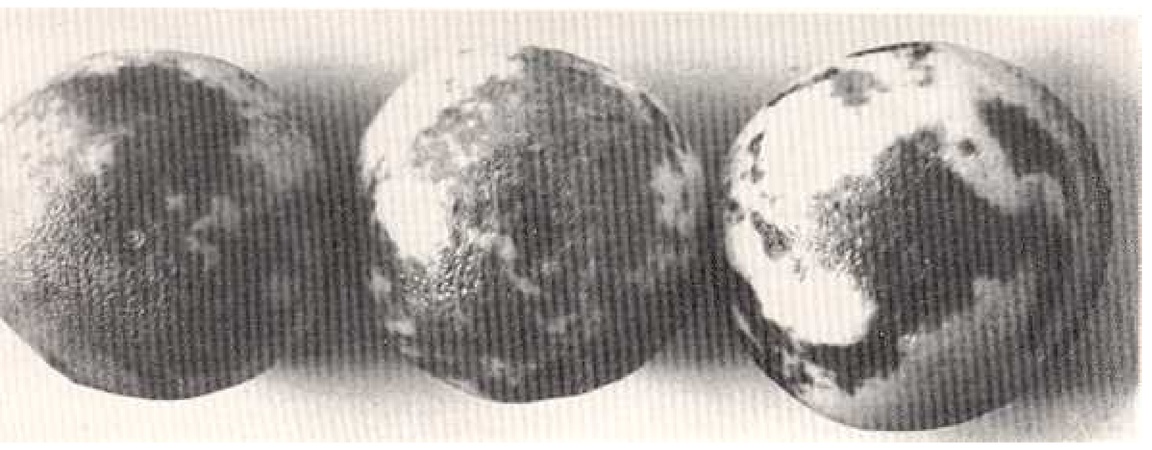
TABLE 14.—PEEL BREAKDOWN OF TEMPLES SUBJECTED TO VARYING PERIODS OF ETHYLENE DEGREENING AND HELD THEREAFTER AT 70° F. FROM GRIERSON AND NEWHALL (*22*).

Days in Degreening Cabinet	Ethylene	Days from Entering Degreening Cabinet			
		3 Days	6 Days	9 Days	18 Days
		Percentage of Fruits Injured*			
1	Normal Concentration	0	0	4	6
2	Normal Concentration	0	16	30	54
3	Normal Concentration	2	40	64	74
3 (Control)	None	0	0	0	0

* For type of injury see Fig. 23.

"Gas Burn" or "Ethylene Burn" of Temples.—A very serious "burn" or skin breakdown of Temples caused by ethylene (Figure 23). The amount of this injury is related to both the ethylene concentration used (Figure 24) and the duration of exposure to ethylene (Table 14). A factor that makes this trouble hard to recognize is its delayed appearance. It seldom appears until at least 2 days after removal from the degreening room and can continue to appear for as long as 18 days from picking (Table 14). Because of this, Temples shipped in apparently excellent condition can develop severe rind breakdown during shipment

Fig. 23.—Peel breakdown on Temples caused by ethylene. (See also Figure 24 and Table 14.)



and marketing. In view of this it has been suggested that ethylene degreening of Temples might well be prohibited (*22*).

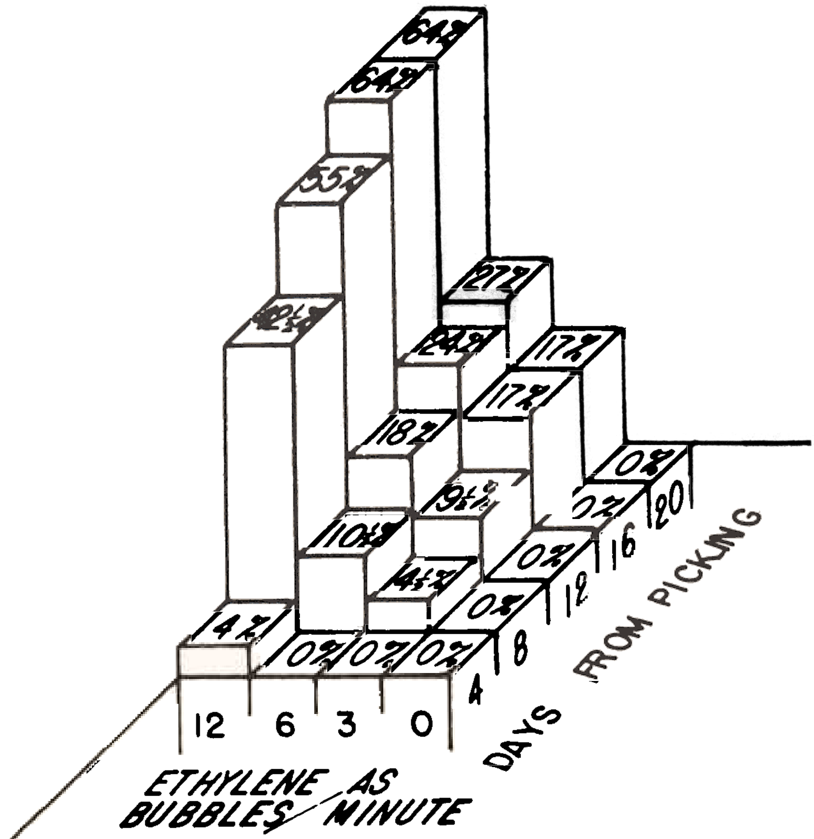


Fig. 24.—Peel breakdown of Temples held for 2 days at 85° F. in various concentrations of ethylene (6 bubbles per minute approximates normal concentration) and held thereafter at 70° F. Note that in all ethylene-treated samples, fresh injury continues to appear to or beyond 16 days from picking (i. e., 14 days after leaving the degreening room). From Grierson and Newhall (*22*). (See also Figure 23 and Table 14.)

Handling Damage of Tangerines.—Tangerines that have been degreened become particularly sensitive to various forms of handling damage. This is illustrated by the results from a commercial packinghouse presented in Figure 25. The damage pattern shown here corresponds closely to that in many experiments carried out at the Citrus Experiment Station. **Tangerines that have been degreened behave quite differently from those that have not.** Not only do degreened tangerines suffer more damage due to the polisher brushes, but this damage is not repeated by

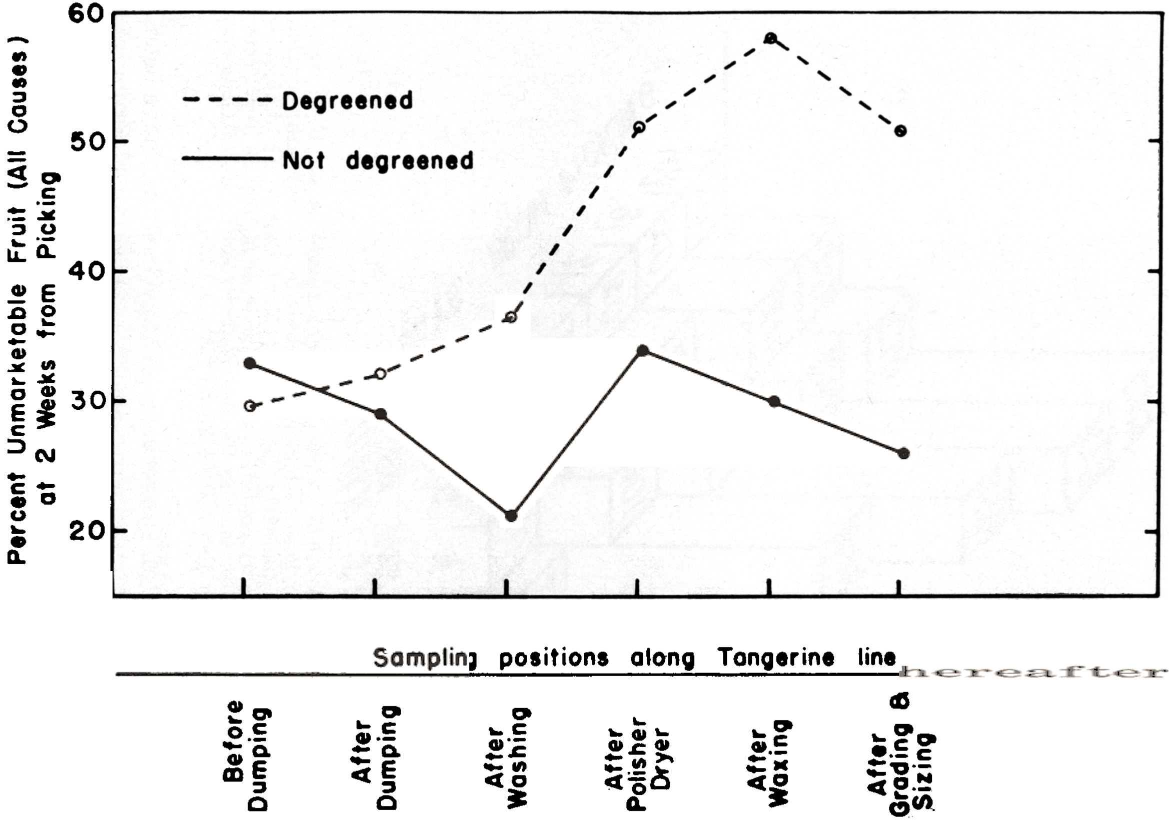


Fig. 25.—Handling damage in degreened and non-degreened tangerines processed on a tangerine line in a commercial packinghouse and held thereafter at 70° F.

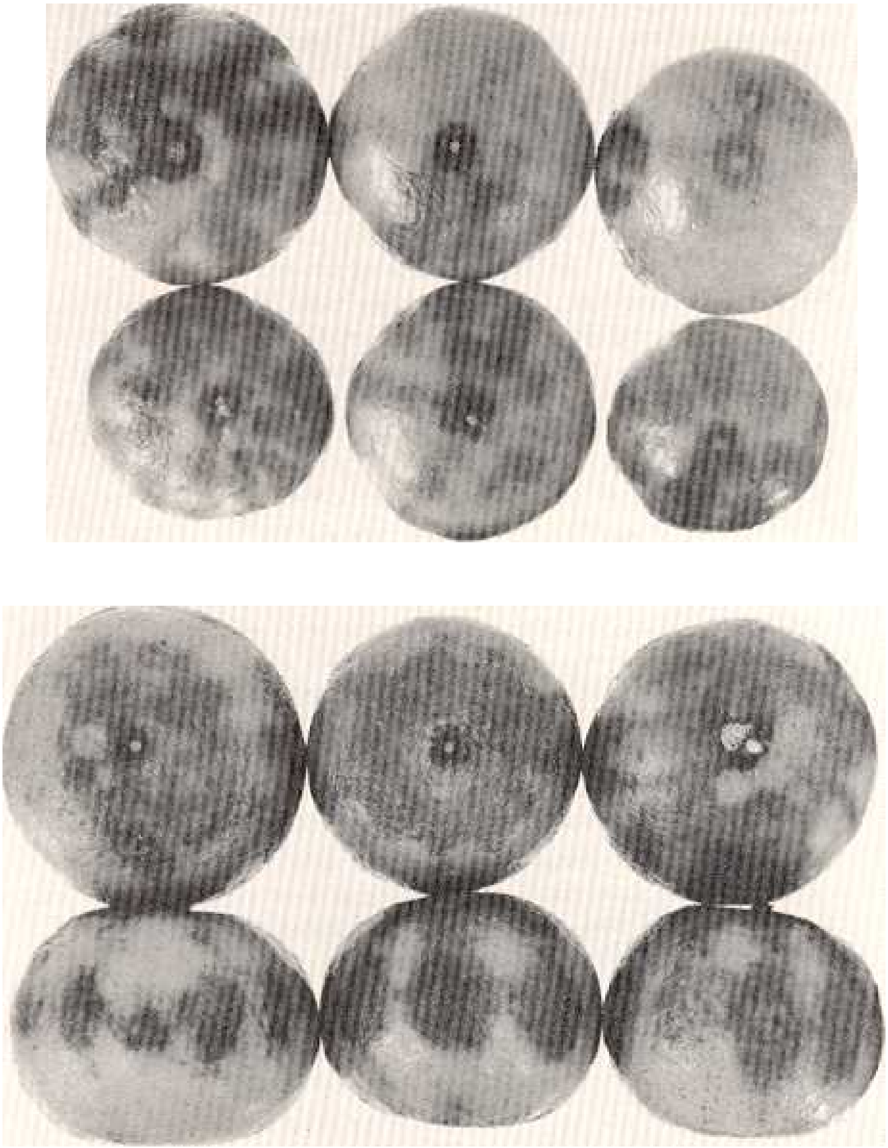


Fig. 26.—Above: Injury to tangerines due to accumulative effect of degreening, polishing and waxing fruit picked without a good color break. This injury appeared approximately 1 week after picking. Below: Injury to tangerines picked with a full orange color and then held in the degreening room while the greener fruits of the same picking were degreened. Photographed 1 week from picking. From Grierson and Newhall (*25*).

waxing, as happens with the non-degreened tangerines. Indeed, additional damage sometimes occurs that is attributable to the cumulative effects of grove conditions, degreening, polishing and waxing.

Figure 26 shows how this injury, which is sometimes called "zebra skin," takes the form of dark sunken areas that follow the divisions between the fruit segments. The discolored fruit also develop an objectionable flavor and soon succumb to decay. This type of injury shows up several days after packing and hence is not often seen in the packinghouse.

The occurrence of zebra skin has been found to be related to the moisture conditions in the grove, the quantity of ethylene used, the duration of the degreening period and the color of the tangerines prior to degreening. A bad outbreak can be expected when degreening tangerines from groves where rain or irrigation has maintained a high moisture level. High ethylene concentrations or prolonged degreeing followed by rough handling, particularly polishing, accentuates this disorder. Losses are apt to be higher in fully colored tangerines that are mixed in with green tangerines during degreening and in tangerines that have no color break at picking. For this reason it is recommended that for at least a week after very heavy rain or heavy irrigation, tangerines be spot picked for color so that they may receive the very minimum of degreening. Because tangerine eliminations are almost invariably handled at a loss (*21*), such spot picking would probably pay for itself in increased pack-out, regardless of the benefits from improved keeping quality.

Peel Injuries of Oranges.—Perhaps the most puzzling form of damage associated with degreening is peel injury of oranges, various forms of which are shown in Figure 27. This can take many forms and is known by many names, e.g., "pitting," "stem-end pitting," "stem-end peel breakdown," "aging," "burnt stem," "brown stem" and "rind staining." Despite considerable studying of this subject, these authors are not prepared either to classify these various forms of injury or to state categorically the role played by degreening. Nevertheless, certain observations may prove helpful.

The predisposition toward peel injury starts in the grove, although extensive checking of oranges from a wide variety of fertilizer, spray and irrigation plots has failed to produce any consistent correlation with particular grove treatments. Some crops will develop peel injury almost regardless of post-harvest treatment, whereas others will withstand considerable abuse without developing any peel injury other than inevitable shriveling. It is with the intermediate crops that have some predisposition toward peel injury that the effect of post-harvest treatments are significant.

With such crops there is a tendency for any treatment at all to increase the amount of peel injury. The role of degreening is indicated in Tables 15 and 16. The figures shown in Table 15 were obtained from Hamlin oranges being run in a commercial packinghouse that still uses kerosene vapors for degreening. It will be noted that in the fruit harvested November 1 up to 3 per-

Fig. 27.—Peel injuries on oranges. Above left: Stem-end peel breakdown on Valencia. Above right: Lateral pitting on Pineapple. Lower left: "Brush burn" on heavily degreened Hamlin. Lower right: Stem-end peel breakdown on Pineapple.

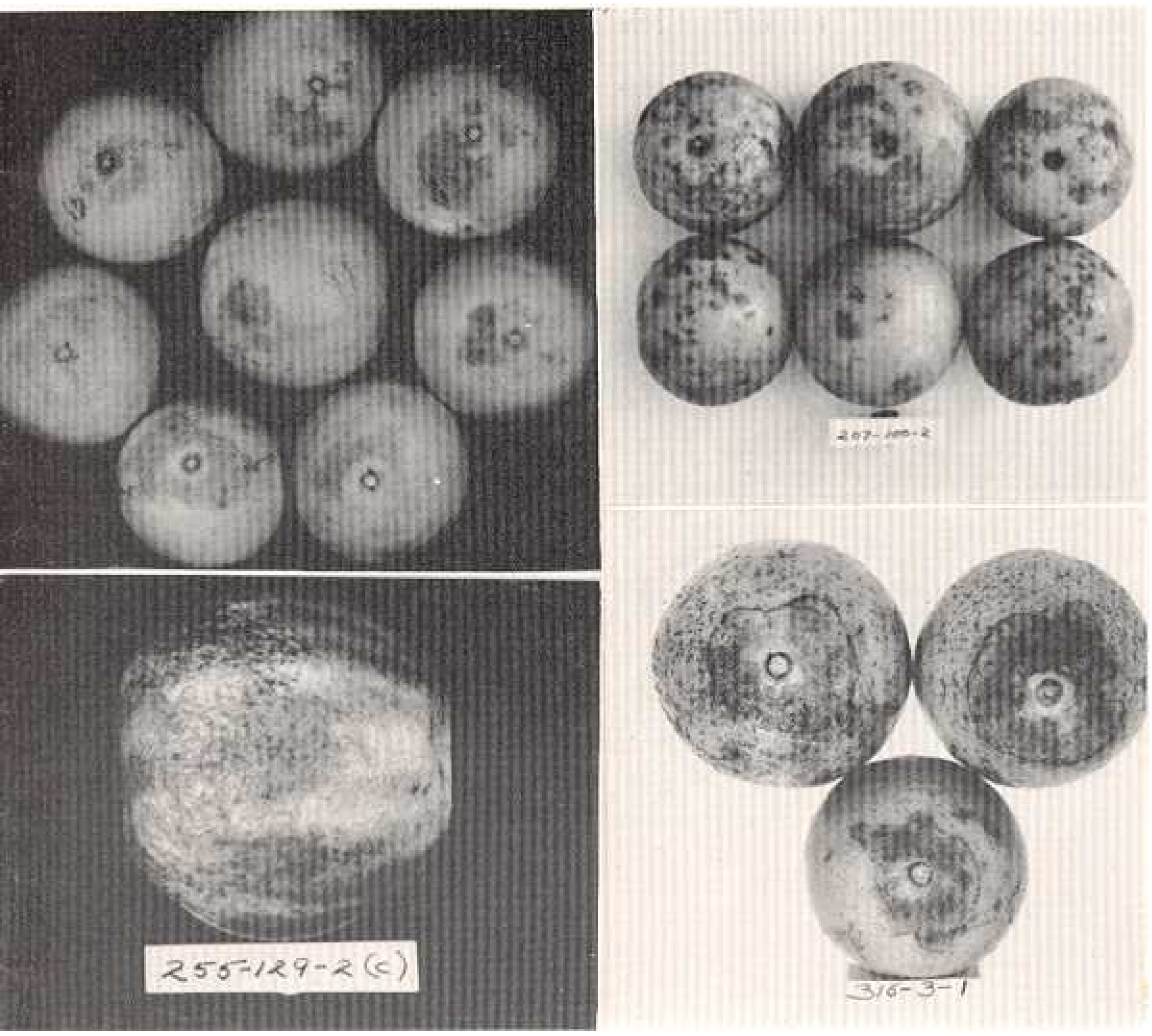


TABLE 15.—OCCURRENCE OF STEM-END PITTING* ON HAMLIN ORANGES AS AFFECTED BY DEGREENING AND POST-DEGREENING TREATMENTS.

Picking Date	Degreening Treatment	Post-Degreening Treatment	Percent Stem-End Pitting after Storage at 70° F. for		
			1 Week	2 Weeks	3 Weeks
Nov. 1, 1954	Kerosene vapors	Unwashed	2	13	13
	Not degreened	Unwashed	1	3	3
	Kerosene vapors	Washed and waxed	32	58	58
	Not degreened	Washed and waxed	7	9	9
Nov. 8, 1954	Kerosene vapors	Unwashed	0	0	0
	Not degreened	Unwashed	0	0	0
	Kerosene vapors	Washed and waxed	2	2	3
	Not degreened	Washed and waxed	0	0	0

* See also Figure 27 and Table 16.

TABLE 16.—EFFECT OF DEGREENING, WASHING AND POLISHING ON PEEL INJURY (PRINCIPALLY STEM-END PITTING) OF VALENCIA ORANGES. DEGREENED FOR 94 HOURS AND HELD AT 70° F. AFTER PACKINGHOUSE TREATMENTS*.

Treatment	Percent Oranges Having Peel Injury		
	1 Week**	2 Weeks	3 Weeks
Degreened only	0	0	0
Washed and polished	21	29	34
Washed, polished, and waxed with a solvent wax	25	29	33
Washed, no polishing, and Lake Alfred 101A wax†	4	9	15

* See also Figure 27 and Table 15.
** Times are from date of picking, which was March 14, 1957.
† This refers to a fungicidal emulsion-type wax developed at the Citrus Station (*53*).

cent peel injury showed up without any treatment at all. Washing and waxing without degreening raised this to 9 percent. Degreening without washing raised peel injury to 13 percent at 3 weeks. But if the fruit from this picking was degreened, then washed and waxed, the amount of peel injury then jumped to as high as 58 percent. The effect of crop variability is shown by the results with the Hamlin oranges picked a week later and handled by this same packinghouse. The only peel injury was a mere 3 percent in the treatment that included degreening, washing and waxing.

In most packinghouses washing and waxing also involves polishing, since the fruit is often dried on a horsehair "polisher-drier." If oranges are liable to develop peel injury, then degreening makes them particularly susceptible to damage from the polisher brushes. With early oranges this may take the form of lateral marking somewhat similar to "zebra skin" of tangerines; with the Valencia variety it is more apt to show up as stem-end pitting (Figure 27). This effect of polishing is shown in Table 16. In this example the comparatively low level of peel injury in the water-waxed sample is due not to the difference in the waxes but to the fact that (in accordance with commercial practice) the oranges that were being treated with the solvent wax were highly polished prior to waxing. The damage is largely due to increased sensitivity as a result of degreening prior to polishing. In many experiments at the Citrus Station this form of damage could be minimized by degreening after washing and polishing instead of before. **This, however, is not a commercial treatment** as prior washing, polishing or waxing slows or arrests degreening.

Table 17 (from Hopkins and Loucks (*40*)) shows how previous degreening also sensitizes the fruit (in this case Valencia oranges) to further damage from the color-add treatment. In fruit that had not been degreened, color-adding increased peel injury from zero to 4.85 percent. With fruit from the same crops that had been degreened, color-adding increased peel injury from 13.25 to 35.5 percent.

The extent to which degreening brings out peel injury is dependent not only on the use of ethylene but also on the conditions within the degreening rooms. Hopkins and Loucks (*40*) have reported that Valencia oranges that developed as high as 23 percent stem-end pitting when degreened under low humidity conditions, developed only 1.5 percent stem-end pitting when degreened under high humidity conditions. Hopkins and McCornack (*41*) have also found that air velocity (as well as humidity) is an important factor. The higher the air velocity the more danger of peel injury, particularly at low humidities. Moreover, since such injured fruit are particularly vulnerable to fungal attack, such conditions can indirectly accelerate subsequent decay (*41*).

TABLE 17.—PERCENT STEM-END PITTING IN VALENCIA ORANGES PICKED APRIL 28, 1952, AND SUBJECTED TO VARIOUS PACKINGHOUSE TREATMENTS. (FROM HOPKINS AND LOUCKS (*40*).)

Replicate	Hours from Treatment when Examined	Degreened for 46 Hours		Not Degreened	
		Color-Added	Not Color-Added	Color-Added	Not Color-Added
I	114 hrs.	40.0	11.5	2.7	0.0
II	90 hrs.	31.0	15.0	7.0	0.0
Averages	202 hrs.	35.5	13.25	4.85	0.0

Degreening also involves a delay imposed between picking and running the fruit through the packinghouse. Any increase in the time between picking and washing, waxing, etc., tends to increase subsequent peel injuries. This is illustrated in Table 18 which shows the effect of various post-harvest treatments on Indian River Pope Summer oranges. Keeping the oranges under moist conditions during any such delay decreases the harmful effect upon peel injuries. Similar effects of such delays have been reported by deFossard (*11*) in a very thorough study of "brown stem" of Valencia oranges in Jamaica, and by Hopkins and Loucks (*39*) and Hopkins and McCornack (*41*) in Florida.

Stem-End Rot.—Various workers have shown conclusively that stem-end rot caused by Diplodia [9] is stimulated by ethylene (*4, 6, 7, 18, 24, 35, 47, 94, 96*). Brooks (*7*) states that a degreening period of 42 to 45 hours caused a 9-fold increase in stem-end rot at 2 weeks from picking. Although such results have been found occasionally in the experiments described here, they are hardly typical. Hopkins, Loucks and Stearns (*35*), reporting results of a large number of such experiments, state that on the average ethylene degreening increased stem-end rot of oranges from 20.8 to 47.0 percent at 3 weeks from picking.

[9] See footnote, page 9.

Such results are essentially similar to those shown in Table 19 in which the effect of ethylene degreening on stem-end rot is shown for a series of 102 experiments on 10 varieties of citrus through three seasons. Throughout this series of experiments the weighted averages show that degreening increased stem-end rot at 2 weeks from picking 2.51 times. Note that the stimulation of stem-end rot shown in Table 19 is due to the combination of all factors involved in the degreening process, whereas that shown in Table 1 is attributable solely to ethylene, since the control samples were held under normal degreening room conditions except that ethylene was not added.

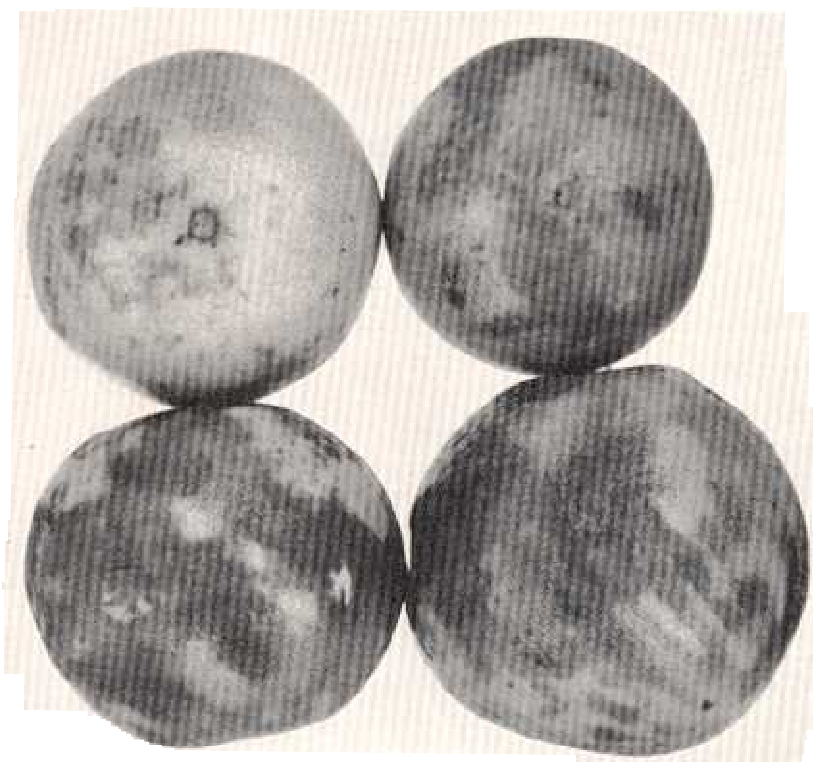


Fig. 28.—"Sloughing" on red grapefruit. Note that where finger pressure has been exerted on the diseased tissue it has slipped off the sound flesh below.

"Sloughing" of Red Grapefruit.—The term "sloughing" is used for this disease for want of a better term. The symptoms are quite striking (Figure 28). The outer surface of the grapefruit turns brown, soft and moist, and at the slightest pressure separates from the sound flesh below. The trouble does not penetrate through the albedo to the flesh, and eating quality is unaffected, although the fruits are, of course, quite unsaleable.

Since this trouble appears shortly after leaving the degreening room, those instances that have come to the writers' attention have usually been blamed upon degreening. This does not appear to be the real cause, since the occurrence of "sloughing" seems to be related to growing conditions rather than to post-harvest conditions (*26*, *28*). Efforts to study and ultimately control this disease are currently hampered by the fact that it occurs only spasmodically (although it may cause almost total loss of a crop when present) and disappears as suddenly as it appears.

TABLE 18.—EFFECT OF POST-HARVEST TREATMENT IN DEVELOPING INCIPIENT PEEL INJURY IN POPE SUMMER ORANGES.

Picking Date (1958)	Percentage Losses from Peel Injury at 1 Week from Picking Date	
	A	B
February 12	6	21
March 3	20	28
March 18	2	22
April 8	2	35
April 24	10	88
May 8	2	77

A = Washed, polished, and waxed immediately on arrival at packinghouse. Stored at 70° F. in closed cartons.

B = Degreened for 48 hours in a very dry degreening room. Washed approximately three days after picking, polished, waxed, and stored at 70° F. in closed cartons.

Blue and Green Molds.—Although blue and green molds are common storage diseases of citrus, the various species of the fungus *Penicillium* responsible for these molds do not thrive at temperatures much above 75° F. Due to the weakening of these fungi by degreening room conditions, losses due to blue and green molds are usually reduced by degreening. This is true for various types of Florida citrus fruits and has been amply demonstrated by Hopkins and Loucks (*36*).

TABLE 19.—EFFECT OF DEGREENING ON STEM-END ROT OF VARIOUS CITRUS VARIETIES, SEPTEMBER 1952 TO MARCH 1955 (ALL SAMPLES HELD AT 70° F. UNTIL TWO WEEKS FROM PICKING DATE.)

Type of Fruit	No. of Experiments	Total No. of Fruit	Average Percent Losses from Stem-End Rot		Percent Increase in Stem-End Rot Due to Degreening	Analysis of Variance "F" Values
			Not Degreened	Degreened		
Tangerines	27	8,100	12.8	26.1	204	60.87*
Hamlin Oranges	18	2,700	5.1	17.8	350	8.97*
Valencia Oranges	17	2,250	7.1	17.4	245	22.32*
Parson Brown Oranges	2	300	26.0	35.5	135	—**
Pineapple Oranges	1	150	8.0	60.0	750	—**
King "Oranges"	1	150	29.0	60.0	206	—**
Temples	14	2,100	11.3	31.2	276	7.48†, ‡
Duncan Grapefruit	18	1,080	3.2	10.7	335	53.86*
Marsh Seedless Grapefruit	2	120	0.0	8.5	—	—**
Foster Pink Grapefruit	2	120	1.0	9.5	950	—**
Totals	102	17,070				
Weighted Averages			8.51	21.3	251	

* Significant at the 1 percent level.

** Too few experiments for statistical evaluation.

† Significant at the 5 percent level (see explanatory note, Table 1).

‡ Losses from stem-end rot reducd (and hence statistical significance reduced) due to losses from peel injury prior to second week examination. See also Figure 23.

SUMMARY

Degreening (the removal of green color by ethylene) is a necessary process in citrus growing districts such as Florida, where luxuriant growing conditions cause chlorophyll to persist or reappear in the rinds of mature fruit.

The degreening process is carried out in special rooms designed to treat the fruit with air containing a low (about 1:50,000) concentration of ethylene at controlled temperature and humidity.

Three types of degreening rooms are described: slatted-floor rooms, solid-floor rooms (both for fruit in boxes) and degreening bins in which the fruit is handled in bulk. In all these it is recommended that air be conditioned to approximately the following conditions: 85° F. dry bulb temperature, 82-83° F. wet bulb temperature; ethylene delivery at 1 bubble per minute per 10-box capacity. Adequate air movement necessitates a fan capacity of 7.5 to 10 C.F.M. per 1-box capacity. (Here the term "box" refers to the Florida field box of 2.232 bushels.) Ventilation to prevent carbon dioxide accumulation should be either a continual intake of approximately 2 percent of the total volume of the room per minute, or else a complete airing twice daily.

The success of the degreening operation is dependent not only upon packinghouse operations but also on the conditions under which the fruit is grown. Review of the literature shows that degreening is retarded or arrested by any factors that tend toward vigorous growth, such as heavy nitrogen or potassium fertilization, certain rootstocks, etc. Oil sprays and the presence of purple scale or chaff scale also retard degreening. A crop from a delayed or scattered bloom period is very difficult to degreen. Color break on the tree is affected by weather conditions; the true orange color of oranges is masked by the presence of chlorophyll until the the advent of cool weather, particularly cool (below 55° F.) nights. On-tree color break of grapefruit shows much less correlation with temperature, the changes proceeding gradually throughout the season.

Degreening affects losses due to various post-harvest diseases of citrus and experiments show that stem-end rot, when caused by *Diplodia*, is increased considerably by degreening. Peel injuries of oranges and grapefruit and sloughing of red grapefruit are also increased by degreening, although the original cause of these troubles usually goes back to conditions prior to picking. The epidermal injury of oranges and grapefruit usually called

"gas burn" has been found to be caused not by ethylene directly but by a combination of moisture and certain unidentified residues on the surface of the fruit under degreening room conditions. A severe epidermal injury of Temples (and to a much lesser extent of tangerines) has been shown to be caused by ethylene, itself, rather than by residues or degreening room conditions. Losses from *Penicillium* sp. (blue and green molds) are decreased by the degreening process due to the weakening of these fungi at tempratures above 75° F.

ACKNOWLEDGMENT

Acknowledgment is made to K. W. Loucks for his assistance with statistical analyses.

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