CRITICAL INDUSTRY REPAIR ANALYSIS
FOOD INDUSTRY

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CRITICAL INDUSTRY REPAIR ANALYSIS

FOOD INDUSTRY

SUMMARY

This report has been reviewed by the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense.

Prepared for the
Office of Civil Defense
Under Contract OCD-OS-62-257
OCD Subtask Number 3311A
by Advance Research, Inc.
Needham Heights, Massachusetts

SUMMARY

SCOPE OF THE STUDY

This study presents an analysis in both the present and postattack contexts of the food industry in the United States. Eight major components of the industry were selected for detailed analysis on the basis of vulnerability due to a limited number of plants and/or on the basis of size and consequent importance in the American diet: flour milling, yeast, sugar, citrus juice, food containers (cans, cartons), edible fats and oils, fish and meat. Doubtless valid reasons could be advanced for substitutions or additions to this list, but such changes would not appreciably affect the outcome in terms of postattack conclusions on a national basis.

The primary concern of this report is repair analysis of damage to food factories following thermonuclear attack. This necessitates touching on all of the elements in the highly complex chain of the nation's food lifeline; agriculture, manufacturing, transportation, wholesaling, retailing, and finally, consumption. However, major emphasis is placed on damage and repair analysis of manufacturing plants, with secondary emphasis on the economics and logistics of food. Agriculture is not analyzed in any depth, inasmuch as its extreme geographical dispersion leads to the assumption that it will be available in a postattack environment.

GENERAL APPROACH

The opening chapter reviews major developments in the food industry, and analyzes anticipated future trends of postattack significance. It is intended to serve as general background material.

The investigative procedure followed certain logical steps. First, the food industry was studied to determine the critical areas, in terms of the contribution of its various components to the diet and to nutrition, and also in terms of vulnerability. With the exception of the citrus industry, geographical concentration was not, as it turned out, a major problem for the industries studied Next, a company in each of the selected fields was contacted, and field visits were arranged so that blueprints, structures, and processes could be studied and, based on them, the vulnerability calculations and recommendations could be determined. In all cases, the manufacturers were most cooperative.

Some of the more important items investigated and reported are geographical locations of major food-producing areas, processing plants, diet, and plant production capacity. With certain exceptions, the industry is so widely scattered throughout the United States as to make the producing and processing of the major foods relatively invulnerable; in any event, it is unlikely that the industry could be reduced at a rate higher than the population it serves. The principal foods which make up the American diet are described with their respective volumes. Many food plants operate at less than 100 per cent of capacity; increased production potentials are discussed where appropriate, both with and without use of extra shifts.

CONCLUSIONS

General

An overall food shortage, as such, is improbable under most foreseeable postattack conditions. In addition to the vast surpluses stored and available in an emergency, the producing farms and factories are so numerous and so geographically dispersed as to preclude their destruction on a scale greater than the demand they would be expected to fulfill. The area of concern, then, is distribution. Of primary concern is petroleum. Petroleum powers the tractors, combines, trucks, trains, and ships that harvest food and transport it to markets. It is estimated that homes, supermarkets, and warehouses can, on the average, supply adequate amounts of food for a total of six to eight weeks; beyond this, unless food can be brought in to the great urban population centers, serious shortages would almost certainly result.

Geographical dispersion

The production of food begins with farming -- agriculture and animal husbandry-- and farming is well-dispersed across the nation, most of which is arable. The food manufacturers are also widely scattered, with minor exceptions, and this dispersion makes for lessened vulnerability. Exceptions to this general rule include yeast, with plants limited in numbers and located in population centers, and the citrus industry, 70% of whose production comes from a narrow belt running across central Florida.

Fallout shelters

There were no shelters in any of the plants visited, although in most cases suitable sites for fallout shelters existed. An exception to this is the Maine sardine plant, with light wooden construction that dictates evacuation of personnel to shelters located in buildings less vulnerable to fire and blast. A suitable industry fallout shelter program, perhaps with appropriate incentives, could help to assure the presence of the repair personnel necessary for recovery.

Shutdown problems

No serious shutdown problems were found. In this respect, the food industry has an advantage over certain others, such as steel, where panic shutdowns can be very damaging. At worst, production could be delayed 2 - 3 days while decayed food is cleaned out of processing pipes and equipment; no such problem exists in the case of cans and cartons.

Cannibalization

The diversity and specialization in the industry tend to minimize the opportunities for cannibalization. Because an edible oil refinery and a juice plant, have little in common in the way of equipment, there is no opportunity for exchange of parts. Opportunities are limited even between like plants, as evidenced by the fact that the two citrus plants visited had different types of juice extracting machines. In general, the best opportunities lie within each plant itself where, for example, usable parts from a damaged juice extractor could be used to restore another, thus initiating limited operation.

Substitutions and shortcuts

With the possible exception of milk for infants, no food is essential and a wide range of substitutes exists to replace the unlikely loss of any one food. A similar range of shortcuts exists, chiefly because many food manufacturing operations are, in reality, refinements of foods already edible, e.g., raw sugar, raw wheat, and whole oranges. If damage makes partial processing necessary, operation can be greatly simplified: whole wheat flour can be substituted for white flour, hotpack ("canned") juice for frozen concentrate, and "fancy" edible oils dropped in favor of a limited number of basic ones.

Bottlenecks

While manufacturing would appear to be the bottleneck in the food industry, results of the investigation lead to the conclusion that this is not so, because of the geographical dispersion and size of the industry, and the opportunities for shortcuts and substitutions. The probable bottleneck is transportation which depends, in turn, on petroleum. Both lie beyond the scope of this study.

Limited production capability

Food manufacturing facilities permit almost any amount of reduction -- in amounts or numbers of varieties -- of output, as a result of damage or of reduced amounts of raw materials; this contrasts with other industries, such as petroleum, where designated flow rates confine the rated capacity to certain narrow limits.

Increased production capacity

This capacity varies considerably, depending on the type of food manufacture, and, in some cases opportunities are limited. The edible oils plant, the yeast plant and the flour mill, maintain 3-shift, 7-days-a-week operations the year around and are operating at or near capacity normally. Orange crop limitations imposed by frost are difficult to control, and sardine packing is limited by the size of the catch, again unpredictable. However, on an individual plant basis, both the juice and fish plants are capable of greatly increased production, provided of course that they are not badly damaged and that their respective raw materials are in abundant supply, perhaps as a result of being diverted away from damaged or destroyed plants to which they would normally have been consigned. The sugar and can and carton plants operate on 5-day weeks and here a 7-day week should increase production proportionately.

Vulnerability

In general, it may be concluded that the older the plant the less vulnerable it is. Plants studied may be arbitrarily broken down into high vulnerability, medium vulnerability and low vulnerability categories, with the total-destruction overpressure ranges in each category, as follows: high, sardine plant and carton plant (1.2-7.0 psi); medium, citrus juice plant, sugar refinery, flour mill (10.0 - 12.0 psi); low, edible oils refinery, can plant, yeast plant 12.0 - 14.0 psi).

The last three are all of the older, massive type of construction which proves to be generally much less vulnerable than the more sophisticated modern type which is built to much closer tolerances.

While vulnerability varies considerably from one plant to another, the modes of failure are generally similar. As blast overpressures increase, structural damage will increase to the point where the structure will collapse and, in so doing, damage or destroy the machinery within at much lower overpressures than those to which the machinery itself would be directly vulnerable. Of nuclear effects, fallout is the least damaging to the food industry, and at worst, panic shutdowns associated with fallout danger will cause minor delays and inconvenience at startup, with little damage. Also, there is little vulnerability to thermal radiation, due in large part to the cleanliness and absence of trash and litter at the food plants.

Nuclear blast was found to be the major cause of damage and, as shown by the above total-destruction overpressure figures, the vulnerability to blast varies greatly from building to building. Some of the more important factors in determining damage at a given blast level are the type of siding (corrugated metal and cinder block fail at much lower blast pressures than concrete walls); the amount of fenestration (the greater the window area, the more rapidly inside and outside pressures are equalized, thus lessening damage to walls and roofs); and framing (steel is superior to reinforced concrete, due to the metal's greater ductility).

Repair

The plants all have good maintenance shops which could greatly assist postattack repair, provided, of course, that the repair facilities themselves were not destroyed by the blast, and that repairmen are available. Priorities should be assigned in any repair plan, beginning with the maintenance shop itself, then repairing facilities and equipment which will be capable of at least restoring limited production in the shortest possible time. Most of the food plants are somewhat less automated and less integrated than are plants in industries such as petroleum, steel, or electric power, and thus repair problems are correspondingly simpler.

Trends

Many food manufacturing industries, such as baking, containers, edible oils, and meat are proliferating in the number of their facilities However, warehouses and retail outlets are concentrating their operations to a marked degree, with ever-larger establishments, and fewer of them. In addition, increased efficiency results in less food in the distribution pipeline at any given time, a decided postattack disadvantage.

Recommendations for future study

Analysis of emergency postattack transportation and distribution of food would be a logical sequel to this Food Industry Repair Analysis and to the Petroleum Industry Repair Analysis now in progress. Use of mobile frozen storage space could prove valuable: Refrigerated trucks could both transport and store large quantities of frozen food, and refrigerated ships could store enough meat to supply the needs of 16 million people for 3 months, which could help to feed coastal cities, particularly the eastern megalopolis.

The repair data from the selected plants have not been projected to the entire food industry. In the current petroleum study, methods of accomplishing this are being investigated. For a rigorous statistical approach, it is desirable that a random sample of plants be analyzed, and the data obtained be projected to all plants in the industry by the conventional techniques of standard deviation estimating and curve fitting to the plots of the data against the various parameters.

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FINAL REPORT

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ABSTRACT

The American food industry is analyzed in terms of vulnerability and postattack repair. Processing plants in eight specific segments of the industry are selected on the basis of essentiality and vulnerability: flour, yeast, sugar, citrus fruit, edible oils, fish, meat, and packaging (cans and cartons).

Vulnerabilities of the plants vary by a whole order of magnitude. The most vulnerable plant faces total destruction at a relatively low 1.2 psi blast overpressure, and the least vulnerable plant is still repairable after a blast of up to 12.0 psi. The older, more massively built plants are generally least vulnerable, hence present the fewest repair problems at any given blast level.

There are two general conclusions. First, a severe shortage of both raw and processed food stuffs is improbable, because food manufacturers are both numerous and geographically dispersed. Second, food in one form or another, including ample reserves in the form of stored, surplus commodities, will be available but must be transported. An adequate supply of petroleum is essential to insure the transportation which will provide the food supply.

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Olaf H. Fernald, Principal Investigator

Thomas D. Bull, Editor

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1. NATIONAL PICTURE OF THE FOOD INDUSTRY

1.1 INTRODUCTION

Food is essential in any environment, whether postattack or normal. In a postattack environment. adequate supplies of essential foods will be required, not only to sustain life, but to provide the energy needed in industrial recovery and reconstruction work (see Appendix). Almost all of this food will have to pass through some form of processing or manufacture, and it is the manufacturing plants fulfilling this function which are the subject of this postattack repair analysis study.

This report is designed to contribute to a general description of the postattack environment, in analyzing vulnerability and repair, in depth, for a number of plants. While it emphasizes the manufacturing area, more work remains to be done. For example, it does not attempt to cover the entire food industry in detail, due to limitations of scope and time; moreover, the size and complexity of the American food industry precludes it. A labor force of 5.5 million Americans grows, processes, distributes and sells scores of thousands of different food products, of which any given supermarket may carry more than 8,000.[1]

The postattack significance of this vast number of items lies in the duplication within most categories -- for example, the number of different brands of frozen foods, bread and canned goods competing for a share of the market. This, in turn, suggests that if the brand "X" plant were destroyed by an attack, similar products under the brand "Y" and "Z" labels may be available to help fill the postattack gap while the damaged plant is repaired or rebuilt. But against the asset of this proliferation of brands and products, must be weighed the postattack deficit inherent in today's trend toward ever-smaller inventories and fewer warehouses, which is a result of increased efficiency and streamlining of the manufacturer-to-retail store distribution process. The net result is to reduce the amount of processed food on hand in the immediate postattack period, and such food as is in storage will be more vulnerable because of the decreasing number of warehouses.

Production of major food commodities is shown in table 1-1 on the following page. Seven of the eight industries covered in this report are listed in the left hand margin and related commodities are shown by arrows, to indicate the overall scope of this report. The Department of Agriculture does not include the eighth industry, fish, in the major commodity category, hence its absence in the table. While fish are of minor importance in the nation's diet (cf. 10.2 lbs. per capita consumption of fish vs. 161.1 lbs. of meat)[2], the industry has been included because its raw material is less vulnerable to fallout than are, for example, cattle, and because fish could play an important part in replacing protein lost through heavy casualties among meat animals.

It is a characteristic of the food manufacturing industry that it is an agglomeration of relatively unrelated types of products, processes, and plants.

Table 1-1 Production of Major Food Commodities

Source: Supplement for 1962 to Agriculture Handbook No. 62. U. S. Dept. of Agriculture

Plant	Commodity	Unit	1959	1960	1961	1962 Preliminary
MEAT STUDY	Meats (carcass weight)					
	Beef	Mil. lb.	13,580	14,727	16,296	15,475
	Veal		1,008	1,108	1,045	1,015
	Lamb and mutton		738	768	832	790
	Pork (excluding lard)		11,933	11,605	11,412	11,650
	Total Meats		27,319	28,208	28,585	29,930
	Poultry and Eggs					
	Eggs	Mil. doz.	5,542	5,329	5,307	5,355
	Chicken (ready-to-cook)	Mil. lb	5,230	5,228	5,830	5,800
	Turkey (ready-to-cook)	Mil. lb	1,123	1,162	1,508	1,300
	Dairy Products					
PAPER CARTON PLANT	Total milk	Bil. lb	122.0	122.8	125.5	126.5
	Cheese	Mil. lb	1,383	1,478	1,630	1,570
	Condensed & evaporated milk	Mil. lb	2,743	2,666	2,624	2,380
	Ice Cream (product weight)	Mil. lb	3,355	3,348	3,335	3,370
	Fats and Oils					
	Butter, farm & factory (actual weight)	Mil. lb	1,411	1,435	1,536	1,625
EDIBLE FATS & OILS PLANT	Lard		2,780	2,563	2,517	2,525
	Margarine (actual weight)		1,611	1,695	1,724	1,715
	Shortening		2,252	2,312	2,454	2,700
	Cooking & Salad Oil		1,808	1,915	2,104	2,400
	Other edible fats & oils		8,139	8,603	8,578	9,500
	Total fats & oils (fat content)		12,055	12,321	12,331	13,333
ORANGE JUICE PLANT	Fruits					
	Fresh:					
	Citrus	Mil. lb	6,730	6,776	6,360	6,136
	Apples (commercial)		3,947	3,472	3,835	3,700
	Other (excluding melons)		4,171	3,911	4,018	4,020
	Processed:					
	Canned fruit	Mil. lb	3,982	3,790	4,046	4,113
	Canned fruit juices		2,134	2,160	2,062	2,077
	Frozen fruit juices		1,702	1,620	1,741	2,035
	Dried		778	693	762	676
	Vegetables					
	Fresh veg. & melons	Mil. lb	24,386	26,094	25,420	24,602
	Fresh vegetables		20,124	21,452	20,981	20,229
	Melons		4,262	4,642	4,439	4,436
	Canned		7,603	8,021	8,814	9,674
	Frozen		1,621	1,953	2,110	2,160
	Potatoes	Mil. cwt.	246	257	294	265
	Sweetpotatoes	Mil. cwt.	19	15	15	16
	Dry edible beans	Mil. lb	1,894	1,792	2,001	1,857
	Dry field peas		500	324	350	495
SUGAR REFINERY	Sugar, raw basis	1,000 short tons	2,822	3,076	3,176	3,400
FLOUR MILL YEAST PLANT	Grains					
	Wheat	Mil. bu.	1,121	1,357	1,235	1,095
	Rye		23.1	33.1	27.3	38.9
	Rice, milled	Mil. lb.	2,828	3,529	3,637	3,622
	Corn, grain only		3,825	3,908	3,624	3,512
	Oats		1,052	1,155	1,012	1,028
	Barley		422	431	393	431
	Peanuts, farmers stock basis	Mil. lb.	1,588	1,784	1,743	1,705

For example, the edible fats and oils plant (chapter 7) studied is older, more versatile, and more blast-resistant than many other vegetable oils plants. At the same time, it has little in common with a grain mill; the oils refinery is essentially a chemical plant, while the grain milling operation is almost entirely mechanical.

1.2 GENERAL POSTATTACK CONSIDERATIONS

Numerous studies have touched on the vulnerability of various components of the food industry, and a brief summary of some of these is listed here. Much of the hazard has been assumed to be due to fallout, and this has been studied in some detail, inasmuch as it represents both a preattack (due to weapons tests) and a postattack problem.

1.2.1 Agriculture

Prior reports have covered in considerable detail problems relating to growth of food and its contamination by fallout.[3] Other analyses have covered the possibility of mass fire damage to agriculture.[4] The relatively large portion of the United States which is devoted to agriculture, as shown in figure 1-1, gives a measure of its relative lack of vulnerability. It indicates that nuclear blast would have a negligible effect, due to the widespread distribution of agricultural areas. Blast damage radii are limited to a few tens of miles, even out to very low overpressure contour levels.[5]

Thermal radiation could cause burning of crops; conceivably fires could cause a good deal of damage over quite large areas. Nevertheless, the overall effect on the crop-producing areas of the United States would not be significant.[6, 7]

The nature of the fallout problem is twofold: radioactive fallout can directly destroy the sources of meat, such as cattle, poultry, sheep, and hogs, or the radioactive or fission products can be incorporated into the food and thus become an internal radiation hazard to animals and people. Obviously, the first kind of hazard places an upper limit on the second. Fortunately, the rapid decay of most fission products also helps reduce the hazards.

Radiation due to fallout is easily capable of blanketing the entire United States.[5] Several studies have tried to analyze the effects, the amount of intake by plants, and the level of radiation which can inhibit growth of plants.[8] Generally, these studies have indicated that although the internal dosage is expected to be high by peacetime standards, the level of internal dosage is well below the external dosage which must be anticipated.[9]

The intake of radioactive fallout into animal tissue has been considered in several studies. Fallout could curtail the meat supply either by killing the livestock through excessive doses of radiation, or possibly by rendering meat temporarily unfit to eat because the tissues of the living animal had absorbed radioactive elements. The latter is considered unlikely, however, because if the animal were to survive the external fallout radiation, the amount of radioactive elements that would find their way into the tissues would be so limited that the meat would be edible.[10]

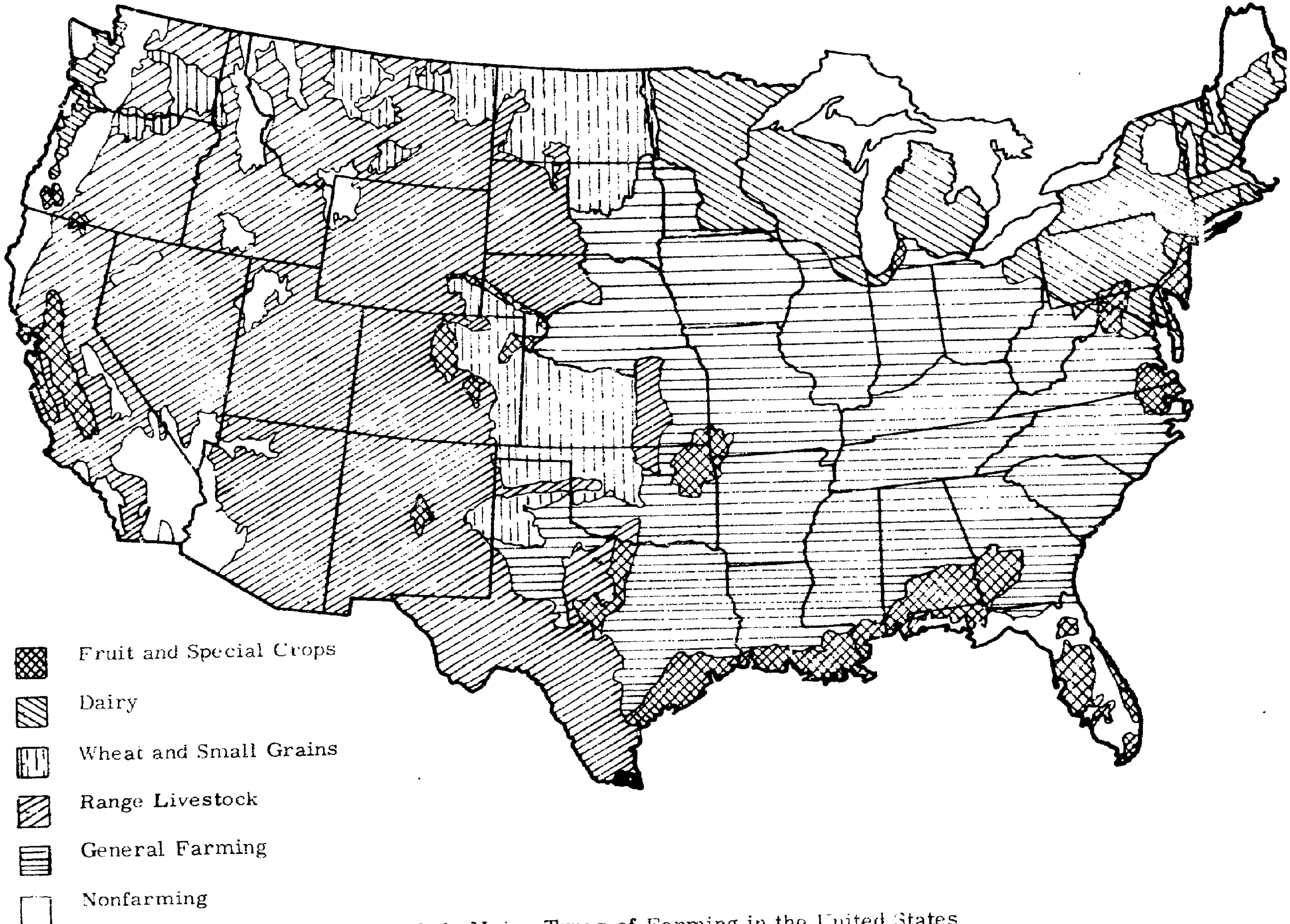

Figure 1-1 Major Types of Farming in the United States
Source: School and Library Atlas of the World, University of Illinois, 1961

The effects of external ionizing radiation on livestock is similar to the effects on persons and causes death at exposure levels not much above that for humans.

The effect of fallout on milk has been the subject of several reports. There are indications that milk is safe for adults in the postattack environment if the cow survives.[11] The needs of infants and children could be supplied from stocks of preserved — canned or powdered — milk, for a few months.

Some studies have attempted to predict major ecological effects on agriculture. For analyses of these possibilities, see the following references: 12, 13.

Another significant characteristic of American Agriculture is large surpluses. This factor is important to the postattack environment because the size of these surpluses gives some assurance that even if agriculture were to be completely disrupted, enough food would exist for many months (see section 2.1.1).

1.2.2 Manufacturing

Food manufacturing is concerned with the 85% of all food which is processed in some fashion. Besides improving taste and appearance, many food processing techniques result in a smaller, more concentrated package, with better keeping qualities — important factors in an emergency situation. Because many waste materials are eliminated at the factory, the costs of transportation and storage are greatly reduced. This means that, in many cases, processed "convenience foods" are less expensive than the less-processed foods from which they are made. For example, instant coffee costs less per cup than coffee made from grounds. Still another value added by manufacturers is nutrition; whether as required by law, as in the case of bread enrichment, or otherwise. Processed foods are designed to capture nutritive values at the peak of freshness and flavor.

The nature of food distribution in the United States shows a concentration, or bottleneck, in the manufacturing area. There are far fewer manufacturers than consumers or farmers, and these manufacturers tend to be concentrated in and near population centers. This report is therefore primarily directed at determining the vulnerability and repair requirements of food manufacturing in the postattack environment. Although considerations were given to the overall problems of agriculture, the general analysis of each specific manufacturer demonstrated the vulnerability of his operation between the incoming raw material on the loading dock and the outgoing product in the shipping area. Industry analysis, and particularly study of the numbers and locations of plants, shows that a specific attack could destroy many of the various industrial components. For example, the number of manufacturing plants in the yeast industry is only 16, and of cane sugar refineries, 22. An example of vulnerability due to geographical concentration is afforded by the Florida citrus industry, which produces 76% of all United States citrus fruit in a narrow belt in central Florida (section 5.1, figures 5-1 and 5-2).

On the other hand, the large number of bakeries (17,886) in the United States led to their elimination as a subject for further study. The meat packers, (over 3000) also were not studied in further detail, although a general logistical study of the meat industry was made.

1.2.3 Transportation

The vulnerability of transportation is not analyzed in this report; its size indicates that it should be considered as a separate industry. Nevertheless, transportation must be considered in any overall analysis of the food problem. Obviously, cities could not exist without adequate transportation, and if transportation were interrupted by an attack, no food could be distributed to them, and the survival of the urban populations would be imperiled. One portion of the study is concentrated on an analysis of the distribution problems associated with the supply of meat to the Northeastern megalopolis (chapter 9) in an attempt to translate the food problem into a transportation, and hence a petroleum problem. However, in the rest of the study a basic assumption was made that transportation was available, in order to isolate and identify problems existing in the food manufacturing area.

Food transportation, of itself, is relatively less vulnerable to nuclear attack than other industry components. Fallout has no effect on trucks or railroad trains, and the network of roads or rails is sufficiently redundant to permit continued traffic flow around any local blast damage. Water transportation is somewhat more vulnerable due to the limited number of targets represented by the major ports.

1.2.4 Distribution

There are 240,000 food stores of all kinds in the United States, making them the most numerous type of retail outlet, but better than two-thirds of all food is sold by some 27,000 of them (11.5% of the total) classified as supermarkets.[1] The locations of these large markets closely parallel the populations they serve, and thus the stores could be expected to survive attack in a ratio as high as, or higher than, the survival of people.

Supermarkets are important not only as retail centers but also as postattack food storage facilities. It is estimated that the food on store shelves and in stockrooms constitutes a one to two-week normal supply on a national basis.[14]

Because the economics of the business dictate rapid turnover, short storage time and low overhead, the warehouses have greatly streamlined their operations. As previously mentioned, the trend is toward centralization — fewer and larger warehouses, with an overall decline in total food stocked. This trend is a disadvantage in terms of vulnerability, although wholesalers are still the largest single factor in food supplies on hand, excluding surplus commodities. Their inventories are estimated to be adequate for a nominal two-to-three week supply on a national basis.[14]

1.2.5 Food supplies

It has been estimated that normal home food supplies are sufficient to last the average family a minimum of 10-17 days under emergency conditions.[7, 14] If the one-to-two weeks retail store supplies and the two-to-three weeks wholesalers' supplies are added, the total comes to an estimated 31-52 days supply. None of these estimates, it should be noted, include edible processor stocks and edible government surplus. If these are added, it has been estimated that sufficient food supplies exist to feed the present population, at a normal rate of consumption, for 110 days.[15] The potential value of these supplies following an attack, even taking into account possible heavy food losses, should be great.

1.3 PRINCIPAL PRODUCTS, VOLUMES AND GEOGRAPHICAL CONSIDERATIONS

Food can be categorized in many different ways; by dollar value, weight, or by nutrition content. Contributions to nutrition undoubtedly are most significant to the postattack period. As detailed in the Appendix, water, food energy, protein and thiamine are most significant to the survival period, in that order. The following table 1-2 lists the percent of various nutrients contributed by major food groups, and the per capita daily consumption of each item, for the year 1961, in the United States.

Meat supplies protein; fats and oils, flour and sugar supply energy; meat and flour are sources of thiamin, and citrus fruits yield ascorbic acid (vitamin "C"). In each case, however, a wide range of substitutes is available.

Food is America's biggest business. In 1962, the nation's food and beverage sales amount to $87 billion; this compares, for example, with $57 billion for defense. $47 billion for building construction, and $24 billion for automobiles and parts, In addition to size and complexity, the food industry is characterized by its competitive nature. This competition results in a vast spectrum of grocery products, with considerable duplication in most categories. In an emergency, many of the product types could be temporarily standardized, and this uniformity could simplify production and distribution.

At most times and in most places in the world's history, there has not been enough to eat, and this is true today. In contrast to the rest of a generally underfed and undernourished planet, the United States stands out as a land of abundance. In terms of the world's total cultivated land, this country leads with more than 1/6 or 17.6%, yet has only 6% of the world's population. This amounts to better than 3 acres of cultivated land per American, as contrasted with China's 1/2 acre per capita.

Most of the geographical statistics are listed under the individual chapters, and will not be repeated here. Suffice it to say that the greater part of the United States is arable, as shown in figure 1-1, and most food industries are widely distributed.

Table 1-2 Contribution to Nutrition and Consumption of Various Food Groups

	Food Energy	Protein	Thiamine	Ascorbic Acid	Calcium	Vitamin A Value	Riboflavin	Niacin	Folic Acid	Daily Per Capita
Dairy products, except butter	13.0%	23.7%	10.8%	6.0%	75.5%	13.4%	46.3%	2.9%	3.7%	16.5 oz.
Eggs	2.3	6.1	2.5	---	2.5	7.4	5.9	0.2	2.0	0.9
Meat, poultry, and fish	14.8	35.2	24.2	1.4	2.8	10.9	18.4	49.0	18.9	8.0
Fats and oils, including butter	20.3	1.9	4.0	---	0.6	9.9	1.0	1.7	0.2	2.9
Dry beans and peas, nuts, soy, and cocoa	3.4	5.7	7.1	0.2	3.6	---	2.8	7.0	19.0	0.7
Potatoes	3.2	2.5	7.0	19.6	1.5	7.8	2.1	6.5	5.9	4.8
Citrus fruit and tomatoes	1.4	1.1	3.9	34.1	1.7	10.9	1.7	2.9	5.8	4.6
Leafy, green and yellow vegetables	0.9	1.9	3.9	21.5	4.0	29.6	3.6	2.6	21.5	3.6
Other vegetables and fruit	3.9	2.4	4.7	17.1	3.8	9.7	4.0	4.8	9.6	9.0
Flour and cereal products	20.9	19.5	31.9	---	3.2	0.4	14.1	22.3	13.4	6.4
Sugar and syrups	15.9	---	---	0.1	0.8	---	---	0.1	---	4.7
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	62.1 oz.
Daily per capita consumption	3180	95	1.76	103	0.99	7000	2.24	20.5	0.129	
	calories	grams	mg.	mg.	grams	international units	mg.	mg.	mg.	

Source: Supplement for 1962 to Agriculture Handbook No. 62, U.S. Dept. of Agriculture

1.4 SELECTION OF PLANTS FOR STUDY

1.4.1 Flour milling

A flour mill and grain elevator were studied. The industry is selected for analysis in view of the large surplus of wheat available (section 2.1.1) and in terms of the vulnerability of the populous northeastern megalopolis between Boston and Washington, because all flour processed for this area passes through Buffalo. Hence, a Buffalo mill was selected for study. The large number of bakeries and their wide distribution eliminates requirements for study of a bakery as such.

1.4.2 Yeast

Fourteen major yeast plants supply almost all the baking industry's requirements and the yeast industry is therefore directly vulnerable, and this vulnerability is passed on, in turn, to the baking industry which largely depends on yeast. The Fleischman's Yeast plant in Pekin, Illinois was selected for study. The plant produces yeast in large quantities, using molasses as the primary raw material.

1.4.3 Edible fats and oils

Edible fats and oils are essential components of many prepared foods and almost all fried foods and bakery items. The company selected was the Durkee Famous Foods Division of Glidden Industries located in Chicago, Illinois. The plant selected, although old, is more versatile than most in the industry and is capable of making virtually any variety or type of product required by consumers and manufacturers.

1.4.4 Fruit juice

Frozen orange juice was chosen to represent processing difficulties appropriate to the frozen and canned vegetables and fruits. The orange industry is considerably more localized than others, and oranges are, for this reason, the most vulnerable of the major agricultural crops. Three quarters of the orange juice consumed in the United States is produced in one narrow belt across central Florida.

Two plants were studied. One is a modern plant constructed immediately after World War II for the particular purpose of processing frozen orange concentrate, the other, incorporated a modern dehydrating facility, and also afforded an opportunity to study "canned" fruit drinks.

1.4.5 Cans and cartons

Canned foods, because they preserve food indefinitely without refrigeration, could be expected to play a vital postattack role. Cans were studied at the Portland, Maine can manufacturing facility of American Can Company, built in 1920, and housed in a three-story reinforced concrete building. Production is primarily for the sardine industry.

A paper carton plant in Needham Heights, Massachusetts, that makes milk cartons, was evaluated. It is a modern plant built in 1957. Milk cartons in particular were studied because of the importance of these cartons to the milk supply, and the relative concentration of the manufacturing facilities. Nuclear attack directed at knocking out the carton industry would be quite damaging to the flow of milk from dairies to consumers.

1.4.6 Sugar

The sugar industry is vulnerable, due to a small number of refineries and dependence on imports for most of its raw material. Accordingly, a sugar refinery operated by Revere Sugar Company, a subsidiary of United Fruit Company, was studied. The plant was selected because it refines raw sugar. Cane is the source of 70% of all raw sugar; the remaining 30% is from cane sugar beets.

1.4.7 Sardines

The sardine industry was studied, in part, because canned fish would be an ideal protein food in the wake of an attack. Canned food lasts indefinitely without refrigeration; also, food from the ocean in a later postattack period would not be affected by fallout contamination.[16] Sardines were studied as being representative of the United States fishing industry.

1.4.8 Meat

Meat and poultry were studied by an analysis of the entire distribution pattern. A packing plant study was considered unnecessary from a vulnerability standpoint, because there are 3,000 of them widely scattered. Transportation in regard to the handling of the vast quantity of beef passing through these plants would be of critical importance, and this was analyzed.

Transportation developments, particularly refrigerated trucks and cars, have radically changed the meat packing picture. Because it is cheaper to transport dressed meat than live animals, the packing centers have relocated close to grazing areas, away from population centers. Transportation and refrigeration, then, are the weak links in this industry. As a result there is a greater number of packers, and this trend makes the industry relatively invulnerable.

1.5 FOOD IMPORTS

The United States is an agriculturally independent nation; in international trade of foodstuffs, it is principally an exporter, rather than an importer.

1.5.1 Significant imports

A very limited number of edible agricultural commodities are imported in significant volume, of which the leading ones are coffee, sugar, and specialty meats. Only these items achieved an import value in excess of $100 million in 1960.[4] Beef imports amounted to only 3.8% of domestic consumption, while the comparable figure for all meats was 3.2%.[4] Wheat imports were less than 1% of consumption, other grains negligible, and we are strong net exporters of grain. The peak import year for wheat, however, was the war year 1943, when imports reached 17.5% of consumption, imported largely from Canada.

1.5.2 Food importation in the postattack period

The possibilities for food importation during a postattack survival period are limited in two principal ways: world-wide availability and transportation. Fortunately, two important foods, meat and wheat, are in relatively good supply in the Western world. Transportation may well represent a more difficult problem.

Wheat may be available from Canada, a major exporter of grains. The rail network linking the two nations, and possible the Canadian railroads, will be in a condition quite similar to our own railroads during the early postattack period. If rail facilities in the U.S. are significantly operable, adequate distribution of our own wheat supplies should obviate the need for importation. The same would be true of beef. Some saving in overall transportation could be accomplished by an integrated international approach to the recovery problem; such considerations are, however, beyond the scope of this report.

1.5.3 Shipping

If internal distribution of foodstuffs cannot meet needs, it may become practical to import food by ship. The major coastal centers of population could be reached and food supplies delivered in this manner, assuming some port facilities survived. The ships could also serve as temporary storage centers for distribution of food thus imported. Some refrigerated ships, such as those now used for importing and exporting beef and bananas could possibly be used for importing, storing and distributing meat from Argentina and Australia. Or, if there were sufficient warning time, the ships could be stocked, as a precautionary measure, with domestic foods in the preattack period.

Two American shipping lines report that they own or charter a total of 47 refrigerated vessels (about half of all refrigerated vessels under American control) with a total storage capacity of 11.0 million cubic feet. This is sufficient space to hold, for example, at least 170 thousand tons of dressed meat at or near $0^{o}F$, which in turn could supply the meat needs of 2.1 million people for a year at the current rate of consumption[17], or 8.4 million people for 3 months. Where port facilities exist, it is quite possible that such ships could enjoy far more maneuverability than land transportation, and could supply the major seaboard population centers as needed. Many of these vessels, however, are on time charter from foreign owners and the charter agreements have cancellation clauses providing for the return of the ships to the owners in the event that the United States is involved in hostilities. What exceptions could or would be made to this is not known, but it appears that refrigerated ships could play a vital role in postattack survival.

1.5.4 Limitations on food imports

As a short-term survival measure, food importation has limits to its practicality. Adequate food supplies will exist within the nation, with their distrubution presenting the central problem. To acquire adequate foodstuffs by importation, with the same or even more difficult transportation problems does not present a complete solution, particularly for cities in the nation's interior.

1.6 TRENDS OF POSTATTACK SIGNIFICANCE

1.6.1 General

Economic considerations are the prime movers of food industry trends, and these normal, preattack trends in turn affect postattack considerations. The economics of a trend determine generally whether it will continue, accelerate, or decline -- hence merits examination. Often a very small economic margin can spell the difference between success and failure of a product.

1.6.2 Recent trends

Recent economic trends in the meat industry (chapter 9) will serve to illustrate. The industry is decentralizing to a very significant degree, with smaller packing houses and more of them. This runs contrary to the overall food industry distribution trend toward centralization with larger supermarkets, larger warehouses, and fewer of both. Cost is the determining factor in both cases -- in distribution, the emphasis is on faster turnover and lower overhead; in the meat industry, developments in transportation (improved highway systems, gasoline and liquid nitrogen refrigerated trucks) have made it cheaper to transport dressed meat by truck than livestock "on the hoof" by rail. Therefore the packing houses are moving away from rail centers such as Chicago and into livestock-raising areas like Des Moines and Denver, so that the livestock travel a minimum distance before processing.

1.6.3 Technological aspects

The technological revolution and scientific explosion now in process is also having a major effect on the food industry, as it has on many other industries. Significant contributions to the development of the industry include improvements in transportation, the control and processing of data, as well as specific technological advances involved in the development of new and different "convenience food" products, or new or better methods of processing foods.

It is quite possible that "convenience foods", which are the most significant recent development in the industry, could play an important postattack role. A housewife with a supply of packaged cake mix, for example, would not have to be concerned with local availability of edible oils or the proper grade of flour. All the ingredients would be there, in the package.

The improvement in transportation and data processing has drastically affected distribution patterns, and the trend is expected to continue. Inventories of food, as a percentage of the amount of food in the "pipeline" to the consumer, have been steadily decreasing. In normal times, this is a cost-saving asset, but in the postattack context it is a serious liability because it means less processed food in transit and in storage, hence less food available in an emergency.

The number of retail stores has decreased drastically, due to the factors listed above and to improvements in consumer transportation and the trends to larger stores. In the period 1958-1963, the number of stores dropped from 400,000 to 235,000.[1] These larger stores must maintain lower inventories relative to their sales volume, due to the rapid large-volume turnover which makes large inventories prohibitive in terms of space and labor. This is compensated by numerous improved distribution services rendered by distributors, wholesalers, and brokers. These "middle men", in turn, have been quite successful in pushing their warehouse inventories back to the manufacturers. In spite of this, however, the manufacturers' inventories have not been greatly increased, due to improved techniques of forecasting demand, improvement in transportation, and decreases in number of warehouses, making fewer, if bigger, customers for the manufacturer to serve.

The trend toward smaller inventories reduces the available food supplies and is unfortunate from a postattack standpoint. However, our ability to generate a surplus of food, which also results from improved technology, might be considered a counterbalancing influence.

Several new technological developments are potentially quite significant from the standpoint of the postattack situation. These include freeze-drying, radiation sterilization, and the development of semiartificial or chemical foods.

Freeze-drying involves the dehydration of frozen foods under partial vacuum, often with the application of microwave energy to accelerate the process. The technique preserves the flavor and nutrition content of the food, while removing most of the weight. Freeze-dried foods, suitably packaged, require no refrigeration for preservation, and are reconstituted simply by adding water. The widespread adoption of the technique would make available quantitites of such foods for postattack distribution. At present, the technique is limited to a few specialty items such as shrimp, because of high costs.

Radiation sterilization involves the application of extremely large doses of gamma ray radiation to packaged foods, killing the bacteria that cause spoilage. The result is a new method of preserving food without refrigeration. The current state of the art of this process permits its application to bacon, but not as yet to other meats, whose flavors are adversely affected.

A very recent development, still in the testing stage, indicates that partial radiation can extend the shelf life of fish up to three weeks, as compared to the present one week. Flavor is not affected, but the fish is, of course, not sterilized; the limited radiation merely retards bacterial growth. Problems include the deterioration in flavor incident to the formation of mercaptans in the meat by the radiation, and cost. While refrigeration is still required with partial radiation, decay is delayed to the extent that fresh fish can be shipped for longer periods of time, hence over greater distances, which could prove of value in supplying fresh fish to postattack populations at considerable distances inland.

Semiartificial or chemical foods have begun to appear in several areas, and the trend is probably an increasing one. Products include some beverages, breakfast cereals and a few others; there are some predictions of the entry of some large chemical companies into the food business. This would be beneficial from a postattack standpoint, in that the foods might store well for long periods of time without refrigeration.

1.7 METHODOLOGY OF THE PLANT STUDIES

1.7.1 Purpose

The purpose of the study, as indicated previously, is specifically the analysis of food manufacturing industries in a hypothetical postattack environment. A study of this problem was undertaken with eight particularly significant elements selected on the basis of importance and/or vulnerability. One or two plants were selected as representative of each one of these phases of the industry, and an effort was made to assure that these plants were typical of their respective industries. Some difficulty was encountered, however, in designating a plant as being "typical"; this is discussed in section 10.7. Very early in the analysis, however, it was found to be quite difficult to settle upon any one plant as being actually typical of the industry and industry people, in particular, were so familiar with the detailed differences between various plants that they found it impossible to concede that any one plant is typical. This is not without some justification as is shown in the striking differences — in processes and vulnerability — of the two citrus juice plants and the two can manufacturing operations (chapters 5 and 6).

1.7.2 Plant inspection visit analysis

The first important stage in preparation for the repair analysis is the plant tour to gain information on typical structures and how the equipment is arranged in and around them. All plants visited had either all, or the major portion, of the equipment housed in the structures.

Structural facilities

During the tour, the type and arrangement of structures can be observed. It is necessary to be familiar with the buildings and their location in order to understand and correctly interpret the calculations, summaries and conclusions obtained by the structural engineers.

Equipment

The equipment is observed for location and type, particularly noting whether it is of massive steel construction made up of a few heavy stationary parts or of many small, intricate moving parts. Some wooden equipment may be found to be sturdy and strong, some light and flimsy. Items made of sheet metal, may or may not be blast resistant, while the more fragile ones have large portions of glass for gauges, meters, inspection panels, etc.

Operation

The operation of the plant is usually the most informative part of the tour. The study of the operation of equipment is important in order to become familiar with the intricacies of the processes involved. From this it is more readily possible to understand maintenance and repair problems, and the real importance of the equipment in the overall framework of the process under study.

Flow of material

If possible, a thorough study is made of the flow of materials through the plant, from the initial introduction of raw materials, through every process, to the completion of the finished product. In this manner, the relative importance of each process and piece of equipment can be determined, and the investigator is better able to determine those areas where building failure or blast damage to equipment would cause the greatest inconvenience. Certain processes and equipment which create special varations to satisfy limited demands, but which are not essential to the quality of the finished product, will also appear in this area of the study. A thorough understanding of this information helps to evaluate the necessity of some equipment. With first-hand knowledge of the operation, of the plant, the flow of material through it, and the importance of each operation, it is possible to make a study of the damage to the equipment and the buildings from nuclear effects. This information is also vital to determine areas of bottlenecking in the process.

1.7.3 Vulnerability analysis

The two major differences between nuclear blast-resistant design and normal design practice are (1) the magnitude of the forces involved, especially of lateral forces, and (2) the time-dependence of these forces, that is, their change in magnitude with elapsed time. The magnitude of overpressure produced by a nuclear weapon can best be appreciated by comparison with wind loading considered in ordinary structural design practice. The customary wind loading, usually expressed as 30 psf, is only 0.21 psi, which is very small compared with the low levels of blast overpressure considered in this report. The dynamic nature of the blast loading has two variant effects. (1) An instantaneous application of the maximum pressure doubles the resistance requirements in an elastic system over those required when the same load is slowly applied. (2) If the duration of the load pulse is short in relation to the natural resonant period of the structure, its full peak value is not effectively applied to the structure, and the static resistance required is but a small fraction of the peak value of the dynamic load.

An exact, rigorous solution for the response of a system to dynamic loading is very lengthy and involved, unless the loaded structure can be assumed to be a simple arrangement of springs and masses and the load-time variation can be defined by a convenient equation. Neither of these conditions is met in the usual structure when subjected to nuclear blast loads; therefore, the first step in solving the problem is to compensate for this fact. Then, by establishing values of two parameters, one based on time and the other deflection, one can estimate the value of a static load (termed the resistance) whose effect on the structure is equivalent to that of the given dynamic load. The structure can then be checked against this equivalent static load by ordinary analysis.

The procedure used in this study follows that outlined in the "Professional Guide on Reducing the Vulnerability of Industrial Plants to the Effects of Nuclear Weapons", FSD-PG-80-8, to be published by OCD, in order to permit rapid assessment of the range of overpressures which might be resisted by a given structure, within a degree of accuracy which is consistent with the formulation of the problem. The magnitude of variations and uncertainties in estimates of blast loading, as well as the difficulties in evaluating the structural parameters involved and the variations in the properties of the structural materials themselves, preclude limiting the inaccuracies in an answer to less than perhaps 25 per cent. These factors, therefore, serve to reduce the reliability and practicality of detailed, numerical approaches to the problem.

Furthermore, since there is a wide range of weapon sizes to be considered, and since peak overpressure varies with the distance from ground zero, the assessment of damage of a precise overpressure for present purposes is somewhat academic. Conversely, the exact overpressure that causes collapse is equally academic. The analyst is interested in discovering what might happen within various ranges of circumstances, rather than for a particular combination of data. The blast resistance of various components of a structure or facility relative to each other is likewise of interest since it points out the weak links.

1.7.4 Repair analysis

Calculations

Following the plant tour, material obtained is arranged for the repair analysis. The structures are studied and calculations made to show what parts of the buildings would fail and at what pressures.

Each building is studied separately, calculations are made, and conclusions are written.

All information on the plant is then tabulated. Damage at progressive stages of blast pressure is indicated to show the effect on each building at blast pressures from zero through to the complete collapse of the facility. Where necessary, the blast effect on equipment exposed to direct blast damage is also indicated.

Structural and process equipment damage charts

The information thus obtained is used in making damage charts, listing each building or piece of equipment analyzed, in a separate column across the top of the sheet, and listing progressively higher blast pressures down the page. As an example, see tables 2-2 and 2-3 on pages 2-28 and 2-29.

Blast ranges

In studying these damage charts various levels of damage can be quite readily discerned. It is necessary to choose three levels of damage. The first is the low blast damage range, where damage is minor and the plant process equipment can be operated immediately after cleanup. The second is the medium blast damage range, where buildings begin to fall, structural material collapses on equipment, and missile damage causes extensive repair requirements before the plant could be operated. The third range is the high blast damage range, where buildings collapse and equipment is badly damaged, requiring major construction and repair work before the plant can be operated again. This range extends to the point where total collapse of all vital process facilities makes it more economical or more feasible to rebuild the entire facility rather than to repair it.

Repair estimates

The repair estimates of the man-days and skills required to restore operation were based on factors customarily employed in the construction industry and techniques discussed in various references.[18, 19] Man-days were used as the measure of the effort involved, rather than costs, to avoid the difficulty of assessing the value of the dollar in the postattack environment. In making the estimates, the job was broken down into reasonably small components, and engineering judgment was used to determine the exact amount of effort required for each particular job. Repair work generally follows this sequence: first, debris is cleaned away and the damage sustained by the various items of equipment is assessed; then parts are ordered as required, and the repair or reconstruction begins. In most cases considered here, few parts were required from outside. The estimates were made with the assistance of plant personnel familiar with the particular facility involved.

Most tasks can be completed either in a shorter time with more men, or in a longer time with fewer men, but the number of man-days required tends to remain more or less constant over a wide range. As more men are added to a job, eventually a level of effort is reached where, regardless of how many more men are added, the job cannot be shortened. Various reasons exist for this. There are time limitations, for example, imposed in the curing of concrete. Also, the fact is that too many men would get in each others way. For the purpose of the estimates, the basic time period for the completion of repair in a given blast damage range was established by the time it took to complete the most lengthy repair task in that range. For example, in the flour mill all tasks were estimated to require at least 20 days for the low damage range, and at least 200 days for the high range, because 20 days was the length of time required to repair the conveyor bridge, and because 200 days was the minimum length of time required to repair the northwest bins which collapsed when 50% full. Although the other jobs could have been completed in a shorter period of time, the overall operation could not, and hence the longer period of time was used for the estimate. It should not be assumed that these estimates of time will remain valid indefinitely, because construction materials and techniques are being improved every year. For example, corrugated metal or plastic siding, which is applied to building frames with a mechanical device, could in the future be applied to a metal frame with an epoxy adhesive, thereby decreasing considerably the time required for application. In a case where only those minimum repairs or renovations necessary, are made to obtain production, the covering used to protect the emergency process may take the form of stripping trees or telephone poles with plastic sheeting or blown off siding. This report however, assumes that sufficient men, material, and equipment will be available for a more-or-less complete restoration using conventional techniques.

A redesign of the plant along a modern or different line, although it could be possibly accomplished with less effort, was not considered because this would require types of skill which may not be available. In general, the total time required for a repair operation will be greater if redesign is involved, since it will involve engineering lead times and a considerable amount of engineering and drafting, which would have to occur first. Minimum times to restore operation were also estimated and are stated.

Recovery chart

The final step is the formulation of a recovery chart which illustrates graphically the repair effort required to initiate emergency operations, to resume normal operations and the number of days required to affect normal operation for each category of damage.

Definitions of personnel

The term "tradesmen" is used in the repair estimates to describe the people who will be engaged to make the necessary repairs on a particular job rather than list the various trades such as welders, carpenters, electricians, masons, etc. For example, the term used with respect to the repair of boiler equipment would describe pipe-fitters, welders, and other personnel used for this purpose. "Laborers" designates no particular skill. Under certain postattack conditions, some unskilled people could be trained to perform these jobs, as is required in some overseas construction projects. The time for training has not been included in the estimates.

1.8 ASSUMPTIONS

The following assumptions were made for, and applied to, each of the manufacturing facilities studied. The need for such standarized assumptions is self-evident, for without them there could be no valid comparisons of the relative strengths of the various manufacturing facilities that were studied, and of the damages they could be expected to sustain.

1. Transportation was not within the scope of this study and was therefor not analyzed in depth. It is assumed, however, that rail and truck transportation are available to bring materials into the plants and to distribute whatever products are manufactured.

2. The repair analyses assume that there are sufficient workers with the disciplines required to accomplish the plant repairs.

3. All blasts are assumed to be from megaton-range weapons. In most cases, air bursts were assumed, although the calculations are not particularly sensitive to the location of the weapon, provided it is in the megaton range. Results are generally not applicable to kiloton-range blasts at similar overpressures, due to the much shorter overpressure duration of the latter.

4. In each case, the blast orientation is such as to cause maximum damage. Generally, this orientation is "front face".

5. Dynamic pressures are assumed to be applied instantaneously (with zero rise time) and are considered uniform for the full height of the structures.

6. Failure criteria are based on ultimate strength considerations for concrete, and on plastic design strength for steel.

7. Where it is necessary to make specific assumptions peculiar to a given plant or its equipment, such assumptions are noted in the individual industry chapters (2 through 9).

8. It is assumed that the plant would be shut down, using procedures as documented in the individual studies, prior to the bomb attack. In a fallout situation, it is assumed that the plant would remain shut down until the fallout radiation intensity has decayed sufficiently for safety of personnel. Decontamination time, if required, should be added to the other repair times.

2. FLOUR MILL INDUSTRY

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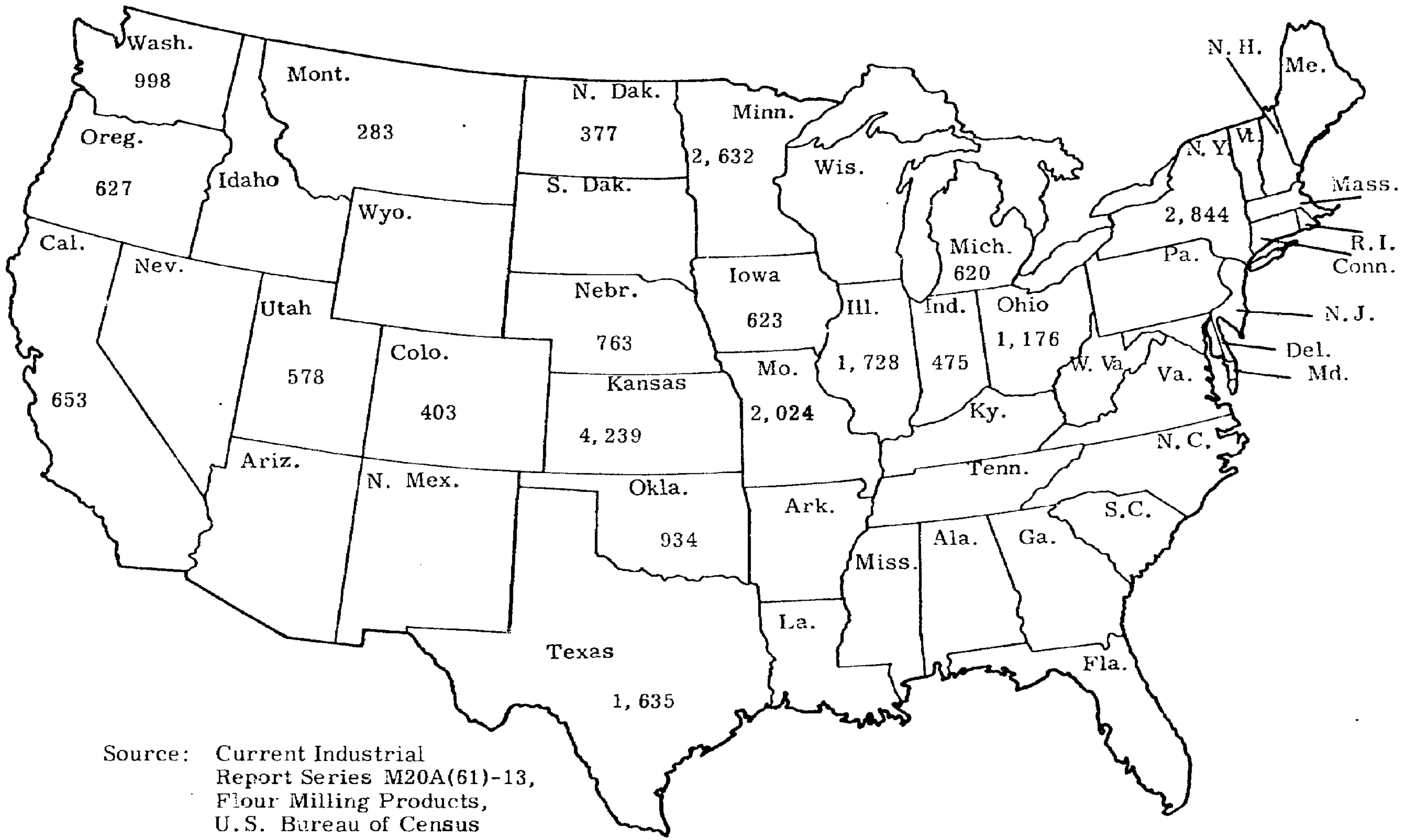


Source: Current Industrial Report Series M20A(61)-13, Flour Milling Products, U.S. Bureau of Census

Figure 2-2 Wheat Flour Production by States (Millions of Pounds), 1961

2.1.3 Bakeries: wholesale, grocery chain, retail

There are 17,886 bakeries of all kinds and sizes in the U.S. Although bakeries are concentrated in large metropolitan areas, they are not very vulnerable to attack, due to their large numbers. Two-thirds of all bakeries are found in the New England, Mid-Atlantic, and East North Central states, in a ratio roughly equivalent to the population. This is shown in figure 2-3.

The largest share of the baking business is done by the wholesalers. They are located in metropolitan areas and distribute their products by truck to supermarkets, delicatessens, hotels, restaurants, and institutions.

Grocery chain bakeries are operated by some of the largest supermarkets chains, who feature their own brand or "private label". Their numbers have increased by better than 25% in recent years, many of them located on main highways but outside of cities.

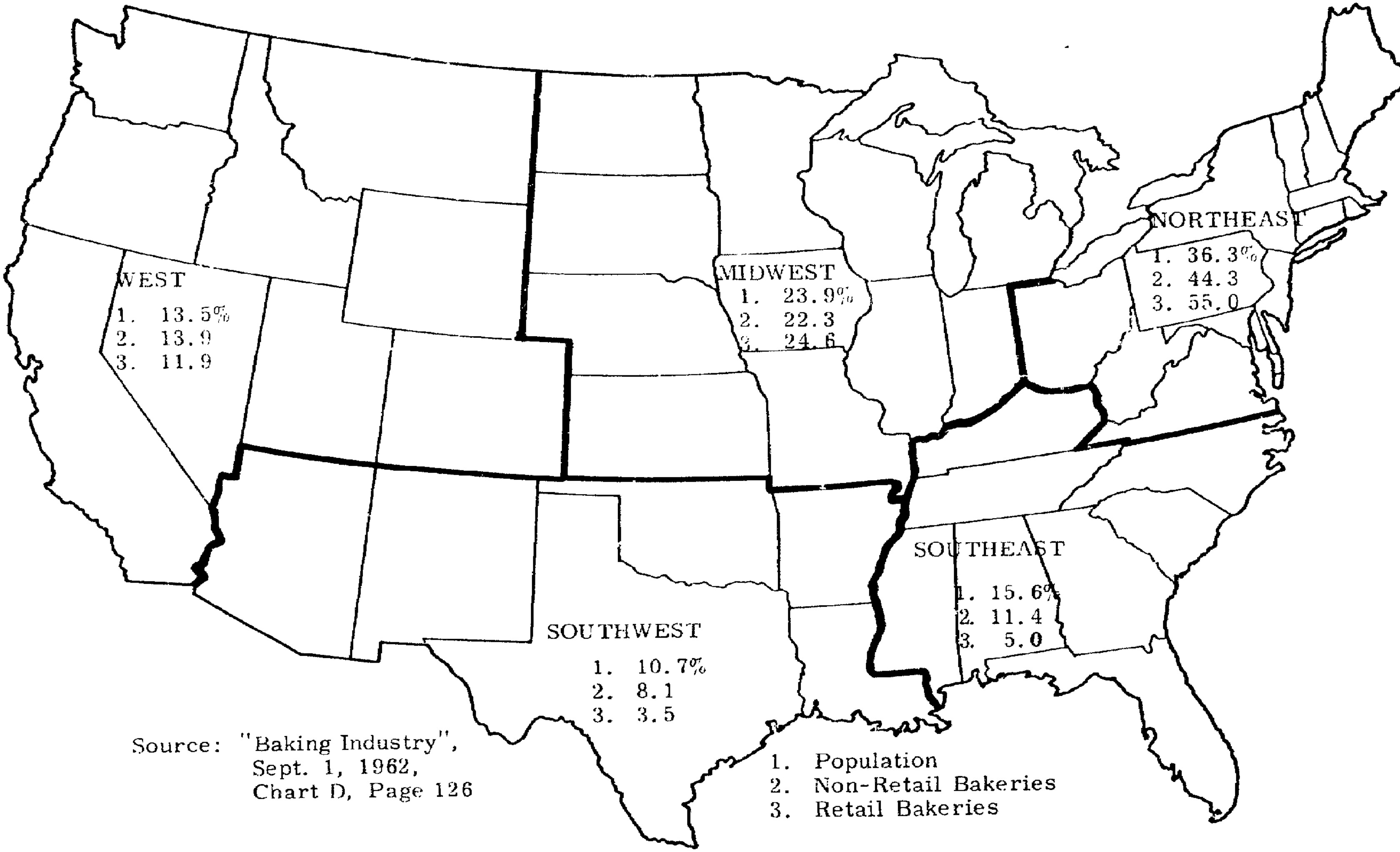
Retail bakeries are the familiar neighborhood type and may be either chain or independent. In the chain, or multi-outlet operation, baked goods are mass produced by a central bakery and are distributed to retail outlets for sale. The independent retailers do the baking on-premises and cater to surrounding territories. Their production is concentrated on rolls, yeast goods, pastries, and cakes. They are increasing in size and volume with annual sales estimated at $737,000,000 earned by better than 12,000 shops.

2.1.4 Trends in the baking industry

It is anticipated that an increasing number of supermarkets will have on-premises baking facilities of their own, to bake products which have been prepared elsewhere and brought in frozen. Estimates indicate that this would prove exceptionally profitable for any supermarket doing an annual business of $1,000,000 or more of which there are approximately 20,000 [1]. This trend would further increase the total number of the outlets many of them located some distance outside of cities, in shopping centers for example, and is therefore favorable in the postattack context.

2.1.5 Wheat varieties

Altogether, there are over 300 varieties of wheat raised in 41 states (shown in figure 2-1), with new varieties being developed on a very rapid basis. These are broken down by the Department of Agriculture into seven principal classes, whose names, sources, and characteristics are shown in Table 2-1. By far the largest single class of wheat is hard red winter, 755,000,000 bu. produced in 1961. This is followed by soft red winter, 203,000,000 bu; white 142,000,000 bu; hard red spring, 116,000,000; and Durham, 19,000,000 bu.



Source: "Baking Industry", Sept. 1, 1962, Chart D, Page 126

Figure 2-3 Percentage of Bakery Sales & Population, by Regions, 1958

Table 2-1 Classes and Characteristics of Wheat

(Based on U. S. Department of Agriculture Bulletin)

	Class No.		Principal States Where Grown	Use	Flour Characteristics	Family Varieties
SPRING	1	Hard Red Spring Dark Northern Spring	North Dakota South Dakota	Bread, Rolls	Has greater strength, more tolerance and higher protein content than flours from other wheats. Provides more gluten and less starch in the dough. Preferred by many bakers, especially for roll and hearth bread and by smaller local shops.	Thatcher Marquis
SPRING	II	Durum Wheat Hard Amber Durum Durum	North Dakota	Semolina for Macaroni, Noodles Spaghetti, etc.	Dough has rubbery characteristics and amber color. Ideal for manufacture of macaroni products.	Kubanka Mindum
SPRING	III	Red Durum Wheat	North Dakota	Animal Feed	Used primarily for animal and chicken feeding purposes.	Pentad Barnatka
WINTER	IV	Hard Red Winter Dark Hard Winter Hard Winter Yellow Hard Winter	Kansas Nebraska Oklahoma Texas	Bread Biscuits	Is less glutenous and has less tolerance than spring wheat flour but more so than soft wheat flour. Often blended by bakers with spring wheat flour. Preferred by many bakers especially in high speed shops.	Comanche Pawnee Turkey Blackhull Tenmarq Kanred
WINTER	V	Soft Red Winter Red Winter Western Red	Michigan Indiana Ohio Canada	Cookies, Cake, and Pastry	Color whiter, with less protein and gluten than hard wheat flour. The low protein and gluten and finer granulation yield tender, fine-grained products	Vigo Fultz Fulcaster Trumbull
WINTER	VI	White Winter Wheat Soft White Hard White White Club Western White	Michigan New York Canada Washington Oregon	Cookies, Pasteries, & Cracker Dough	Has lower protein than soft red winter. Is a weaker flour with less strength, well adapted to pie crusts, drop cookies, etc.	Fortyfold Cornell 595 American Banner Baart
	VII	Mixed Wheat	Includes all varieties of Wheat not included in above classes.			

2.1.6 Transportation

Raw wheat is delivered to the Buffalo, N.Y., mill (see Section 2.2.1) by boat and by rail. The lake freighters, with capacities of up to 450,000 bushels, are loaded at Duluth, Minn., with wheat gathered into the terminals there from farming areas to the west and south. Because the lakes are frozen over in the winter, as much wheat as possible is shipped during the summer season, before winter ice makes the mill dependent solely on relatively expensive rail transportation. Thus the storage elevator at Buffalo is filled during the summer and often several boats, loaded with grain, are left tied up at the dock to help supply requirements throughout the winter.

Early fall rail shipments to the Buffalo mill are received from local areas, such as Pennsylvania and Ohio. Later, fall and winter shipments are received from Kansas and other western areas. This helps keep up the winter milling requirements to maintain a continuous year-round milling program. The storage elevator has a capacity of 4.5 million bushels, and this is continually being used and replaced.

2.1.7 Trends in the flour milling industry

As pointed out earlier, there has been no significant flour mill construction since 1927, but this does not mean that modernization has been neglected. Some mills have installed pneumatic conveyors for handling material to speed up production and efficiency in the existing facilities. It has been possible to increase production sufficiently through innovation, to take care of production increases. Modernization of existing plants will probably continue for many years before any new construction will be necessary, which means that post-attack calculations and planning, based on present construction, should remain valid for some time. Furthermore, as a general rule it has been found that older buildings tend to be stronger than modern ones, because recent changes in design criteria and knowledge of construction materials permit higher allowable stresses. The modern trend is to thinner walls and supporting members, and generally lighter, more flexible, more economical design. This means less mass and, generally, higher vulnerability.

2.2 INTERNATIONAL FLOUR MILL

2.2.1 General description

International Milling Company is an industry leader, with mills in the United States. Canada and Venezuela, see figure 2-4. From the general offices in Minneapolis. International directs the flour mills, formula feed plants, terminal elevators, warehouses and docks, as well as a number of sales offices in the aforementioned countries. With these facilities they produce, sell, and ship products to markets on this continent and to more than seventy foreign markets as well.

All plants, although old, are efficient and equipped with modern milling machinery. Each mill has its own laboratory for testing and quality control. Central laboratories are maintained at Kansas City, Buffalo and Minneapolis, and at Moose Jaw, Saskatchewan, Canada. Minneapolis is also the home of International's research department and commercial test bakery.

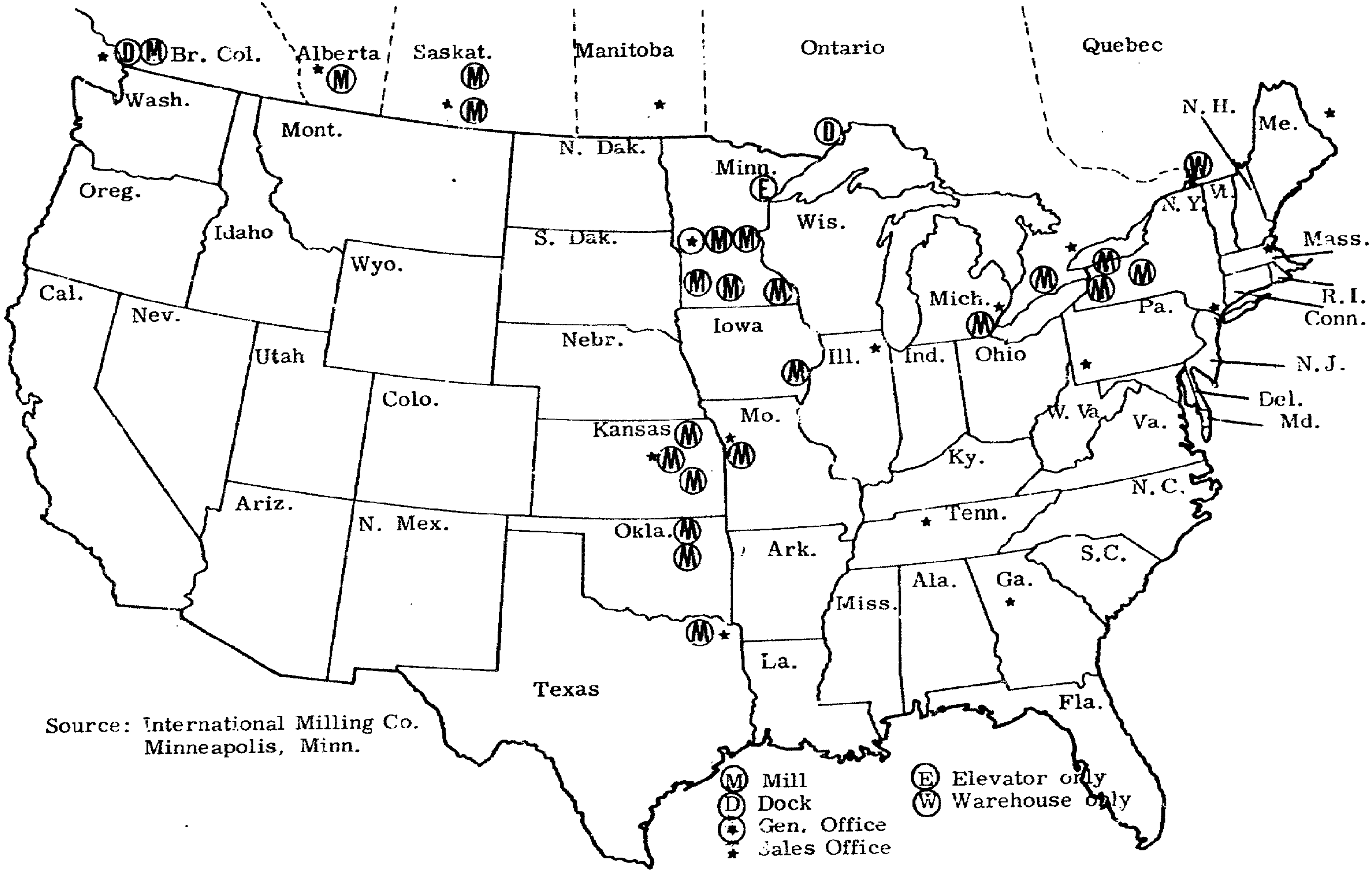
Construction was started on the Buffalo mill in 1926, and the mill began grinding flour in 1927 with a capacity of 5,000 cwt. per day and a grain storage capacity of 1,300,000 bushels. Within a year, this was increased to 13,500 cwt. per day capacity and the elevator to a total of 4,660,000 bushels of grain storage. The Buffalo mill and elevator, figure 2-5, are International's largest.

A plot plan and perspective view of the International Milling Company facilities at Buffalo are shown in figure 2-6. The office building (11) is a three-story brick structure located near the entrance to the property and within easy access to all plant facilities. There are two tall marine towers (1) running on rails next to, and parallel to, the canal. These towers remove wheat from the ship's hold and deliver it to receiving hoppers (2) on the roof of the storage elevator (3). The receiving hopper chute, in turn, delivers the grain through the roof onto conveyor belts in the gallery (5) where it is carried to and placed in bins. Bucket elevators in the head house (4) are used to raise the grain to the gallery for delivery to other locations. The conveyor bridge (6) an elevation of which is shown in figure 2-7 carries the grain to the mill building (7). Flour and other finished products are placed in the warehouse (8), ready for shipping. Railroad cars are filled in the car loading area (9), and shipments received by rail are unloaded by a car dumper (10).

2.2.2 Operation

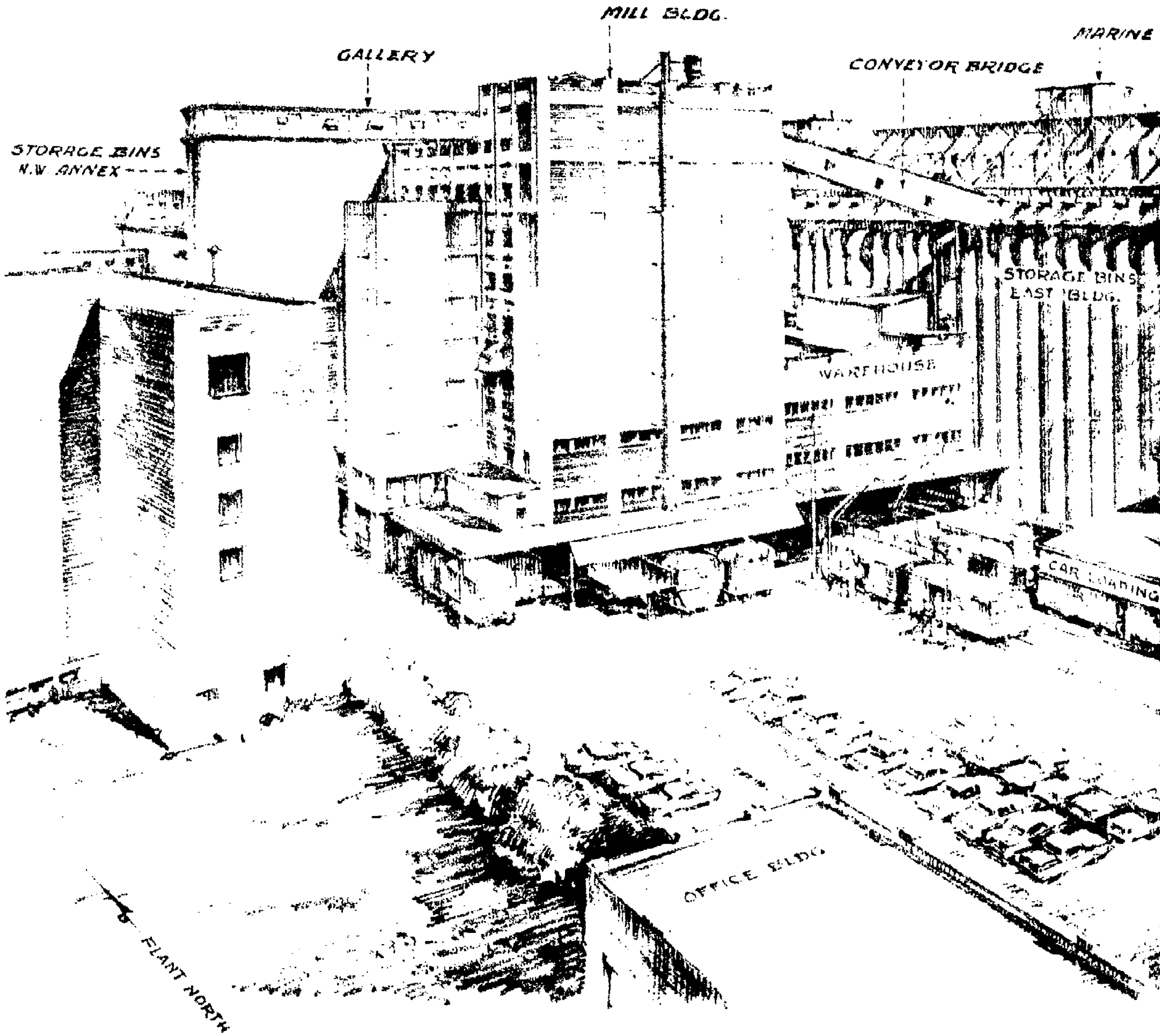
Storage

The minimum supply of grain kept on hand is usually maintained above 100,000 bushels. As previously noted, boats are used for extra storage in winter, with three, four, or five loaded boats tied up before ice stops winter shipping, to be used as the elevator storage is depleted during the winter operations. In addition grain is brought in by rail all winter long. In the course of a year, about 90 percent of the grain arrives by boat, with most of the balance by rail. A very small percentage arrives by truck.

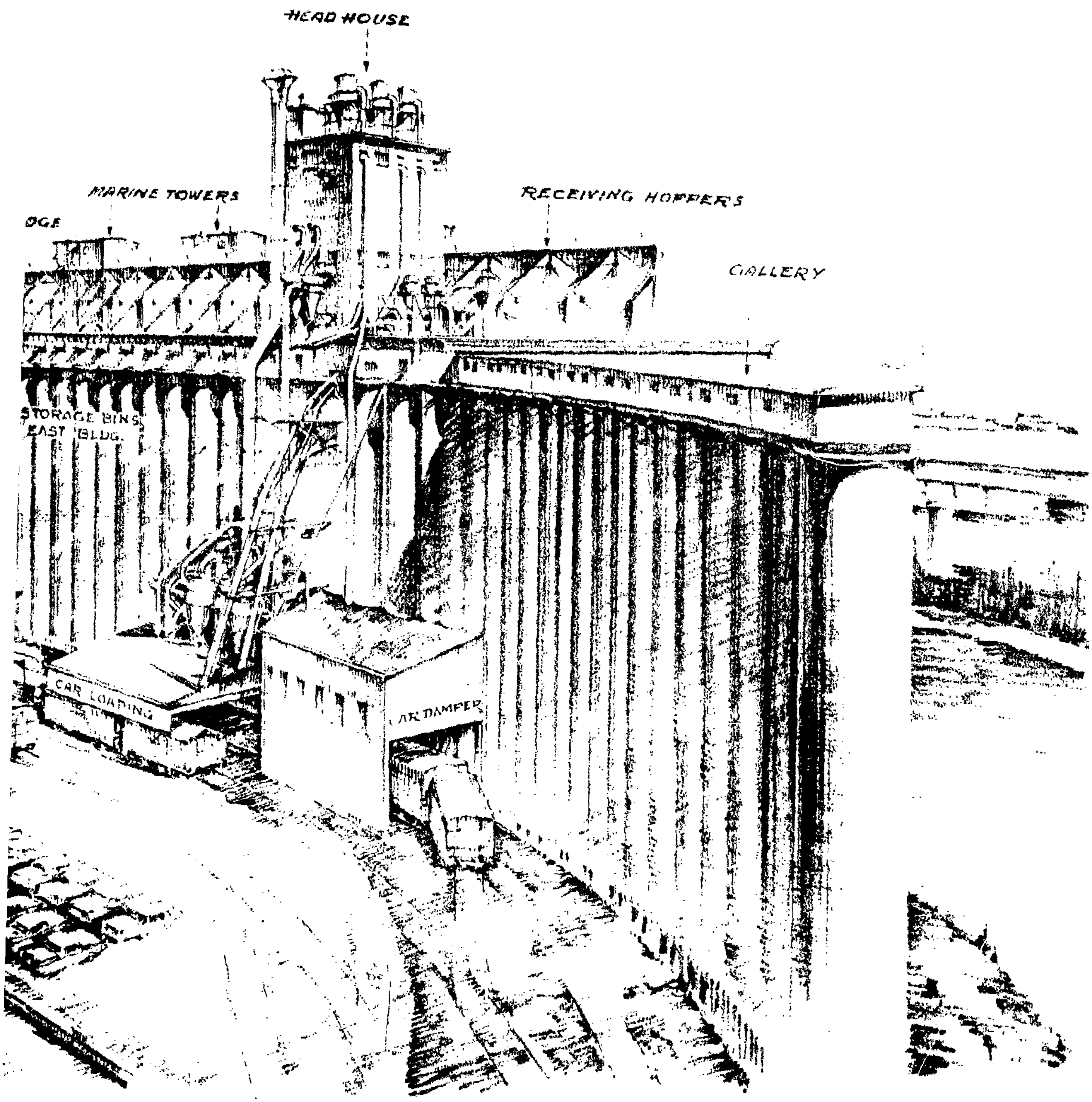


Source: International Milling Co.
Minneapolis, Minn.

Figure 2-4 Facilities of International Milling Co.

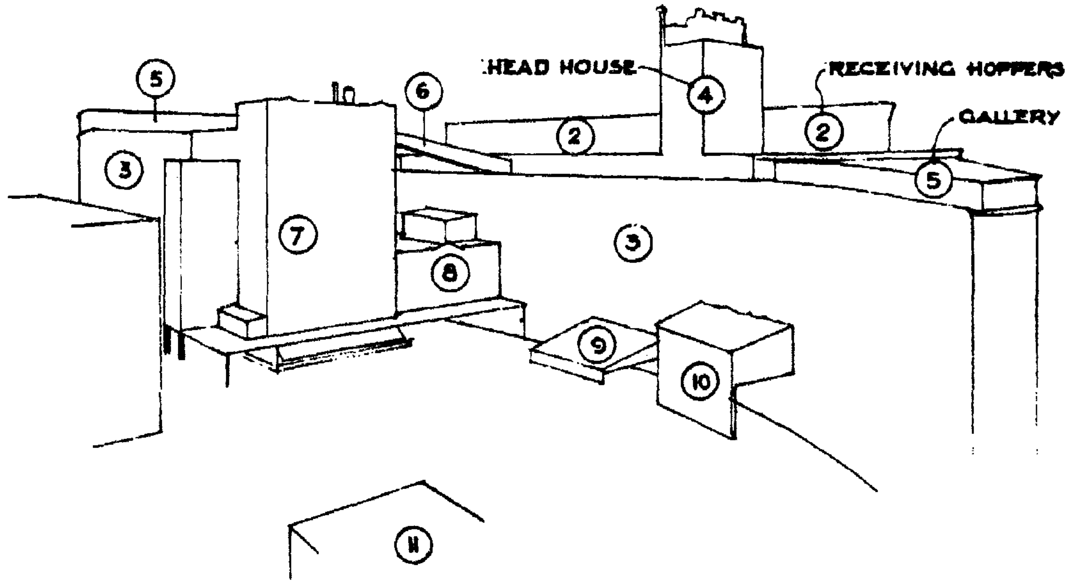

MILL BLDG.
GALLERY
MARINE
CONVEYOR BRIDGE
STORAGE BINS
N.W. ANNEX
STORAGE BINS
EAST BLDG.
WAREHOUSE
CAR LOADING
OFFICE BLDG.
PLANT NORTH

F



Flour Mill

Figure 2-5



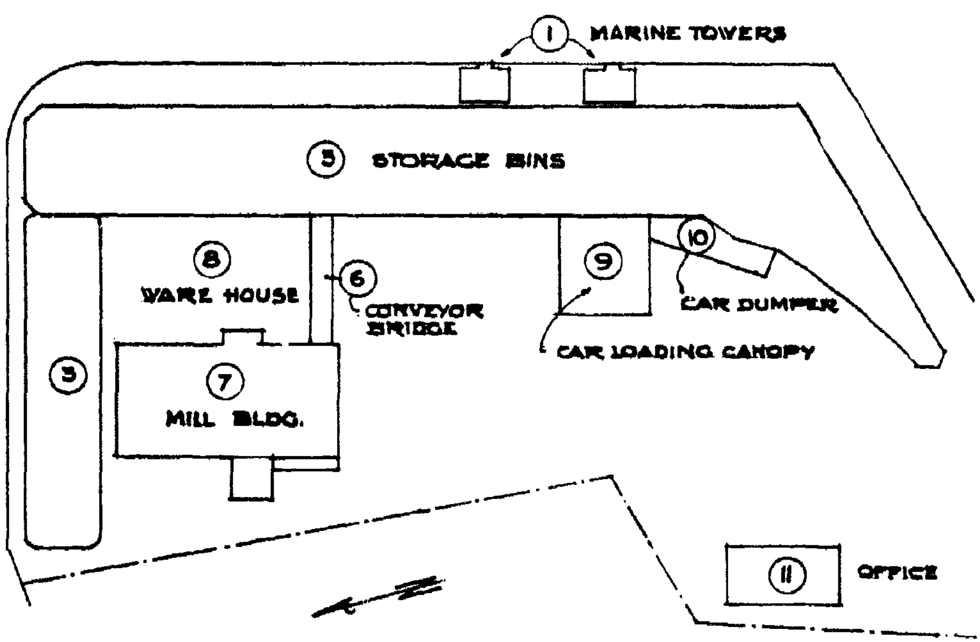
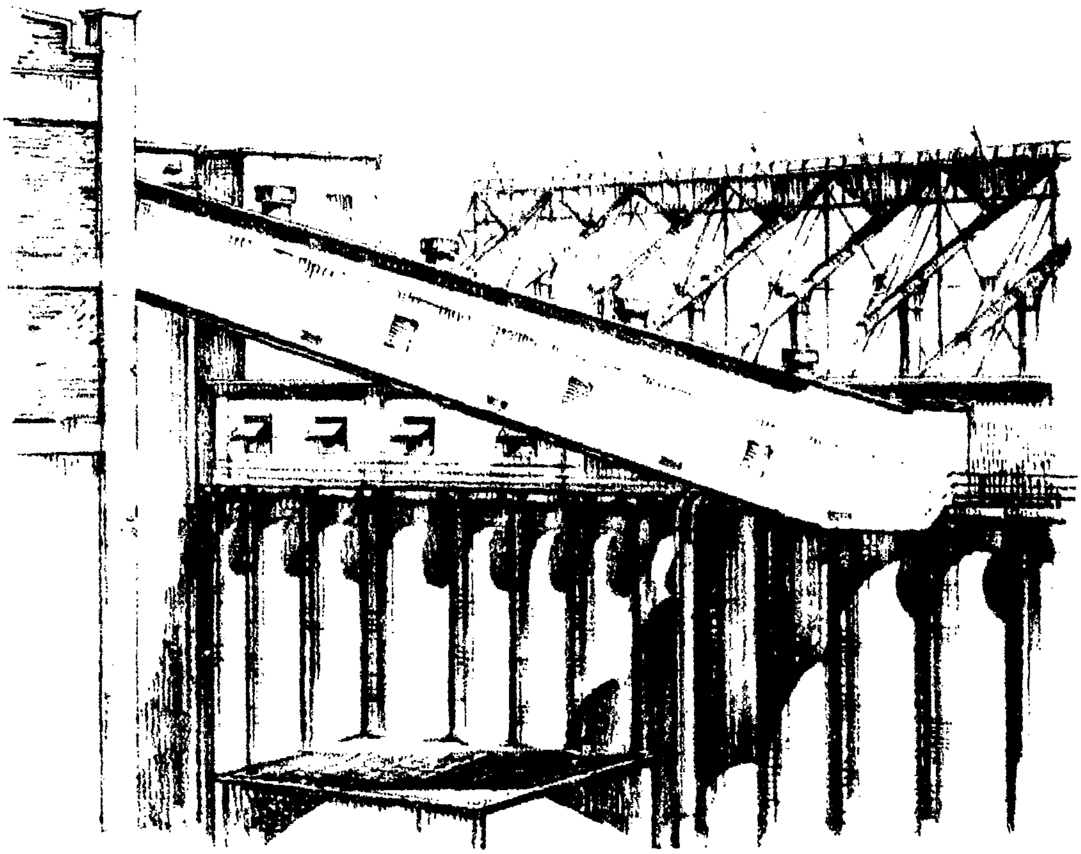


Figure 2-6 PLOT PLAN OF THE FLOUR MILL



Conveyor Bridge at Flour Mill
Figure 2-7

A considerable amount of the stored grain is used to supply other mills. Wheat is shipped by rail to the mills at Baldwinsville and Lockport, N.Y. at the rate of 15 to 20 cars per day, of 2,000 bushels each.

Unloading

The boats are unloaded directly into the storage elevator through the two marine towers, located on tracks so they can be moved along the dockside. The marine leg, or rigid bucket conveyor unit, is lowered into the holds of the ships, to pick up wheat directly and raise it to the top of the leg. Here it is fed into a hopper which at intervals feeds a weigh scale hopper. The wheat is weighed, then dropped into a third hopper to supply a controlled, even flow into a bucket conveyor which raises the wheat to the top of the marine tower. From here, by means of gravity chutes, the grain passes down through the roof of the elevator onto conveyor belts, is conveyed to the bin to be filled and, by means of a tripper, is removed from the belt and fed into the bin.

About 30 stevedores sweep down the hold of the ship and clean cut all the grain. To help speed up this work a scraper, powered by ropes from motors in the marine tower, scrapes the wheat from the sides of the hold toward the marine leg to keep it fed at a maximum rate.

Wheat brought in by rail is moved one car at a time to a location for weighing and dumping. Each car is weighed before and after dumping to determine the amount delivered. A car dumping mechanism clamps the car to hold it in place while the track and platform tilt sideways to allow wheat to flow out the door. Then the ends of the platform are alternately raised to empty the remaining wheat out of each end door. This unit is hydraulically operated and is a vital part of the fast unloading facilities provided. From here, the grain is fed into one of three bucket elevators, raised to the top of the storage elevator and transferred to the bins by conveyor belts in the same manner as wheat is received from the boats.

Storage of wheat

The storage elevator is a reinforced concrete structure with vertical cylindrical bins, as shown in figure 2-5. Proper storage is vital because of the ever-present possibility of spontaneous combustion, particularly if moisture content is too high. Resultant heat damage can render the wheat unsatisfactory for milling purposes. To prevent this, thermocouples are installed at the center of each elevator bin at 5-foot intervals to monitor the temperatures continuously. Should it prove necessary, the wheat can be "turned" by emptying the contents of the bin onto a belt system at the base of the elevators, from which it is relofted by a leg which carries it to another belt system running across the top of the elevators and into a fresh bin. During this process, forced air can be applied to the grain when necessary to reduce humidity and temperatures to safe levels. If in testing, fungi or weevils are found, a fumigant is added to prevent further development. The elevator requires approximately 30 men to operate equipment, supervise the storage facilities, and check the condition of the wheat continually.

The use of atomic radiation to destroy insect pests has been described as a future trend.[20] In a recent experiment by the Department of Agriculture, insect-infested grain was placed on a conveyor belt and moved past a cobalt radiation source. Results were so successful that it has been estimated that annual damage can be reduced by millions of dollars. However, the cobalt radiation was many orders of magnitude greater than that which would result from fallout, and it would be an error to assume that the latter could perform any such beneficial function.

The wheat is stored in large circular bins, and to make efficient use of the structure, the interstices between bins are also filled. Wheat is graded when purchased according to rigid standards as No. 1 Hard; No. 1 Northern; No. 2; No. 3; No. 4; No. 5; feed, etc. These grades are usually maintained through to the storage elevator at the flour mill. To provide the type of flour required by various customers, these grades are mixed prior to going to the mill.

Wheat is received from the top of the storage elevator by a large conveyor belt and is delivered to the tenth floor of the mill, where there are 12 storage bins, four of 3,400 bushels each and eight of 2,400 bushels each. Each bin may contain a different grade or quality of the wheat. These grades are drawn off and mixed according to millers' needs. There are three mills A, B, and C; each runs as a separate unit in regular operations. Total output is 1,800 bushels an hour of wheat of flour and feed, plus 50 bushels an hour of whole wheat, plus 20 bushels an hour of cracked wheat, making 1,870 bushels an hour average total production.

Preparing the wheat for milling

Wheat is prepared for milling in four basic steps: blending, dry cleaning, washing, and tempering, as shown diagramatically in figure 2-8.

Blending is a process of combining various hard and soft wheats in such ratios as to secure the desired protein level and baking characteristics in particular kinds of finished flour. This is accomplished by taking measured quantities of the kinds of desired wheat from the appropriate bins and combining them.

In dry cleaning, all chaff, straw, field dirt, wheat seeds, foreign grains, and other matter are removed from the wheat. This is accomplished by a combination of mechanically agitated screens and a powerful air suction system which removes the finer particles of dust and foreign matter.

After dry cleaning, the wheat is thoroughly washed in plain water and scoured to remove loose outerlayers of fibre.

Then the wheat, already moistened by the washing process, is placed in tempering bins where additional moisture is added under carefully controlled conditions. In this way, the surface moisture on the wheat berry is evenly distributed throughout the interior. The tempering process takes approximately eight hours, but time, temperature, and moisture will all vary according to the nature of the wheat. The purpose of tempering is to permit the easy separation

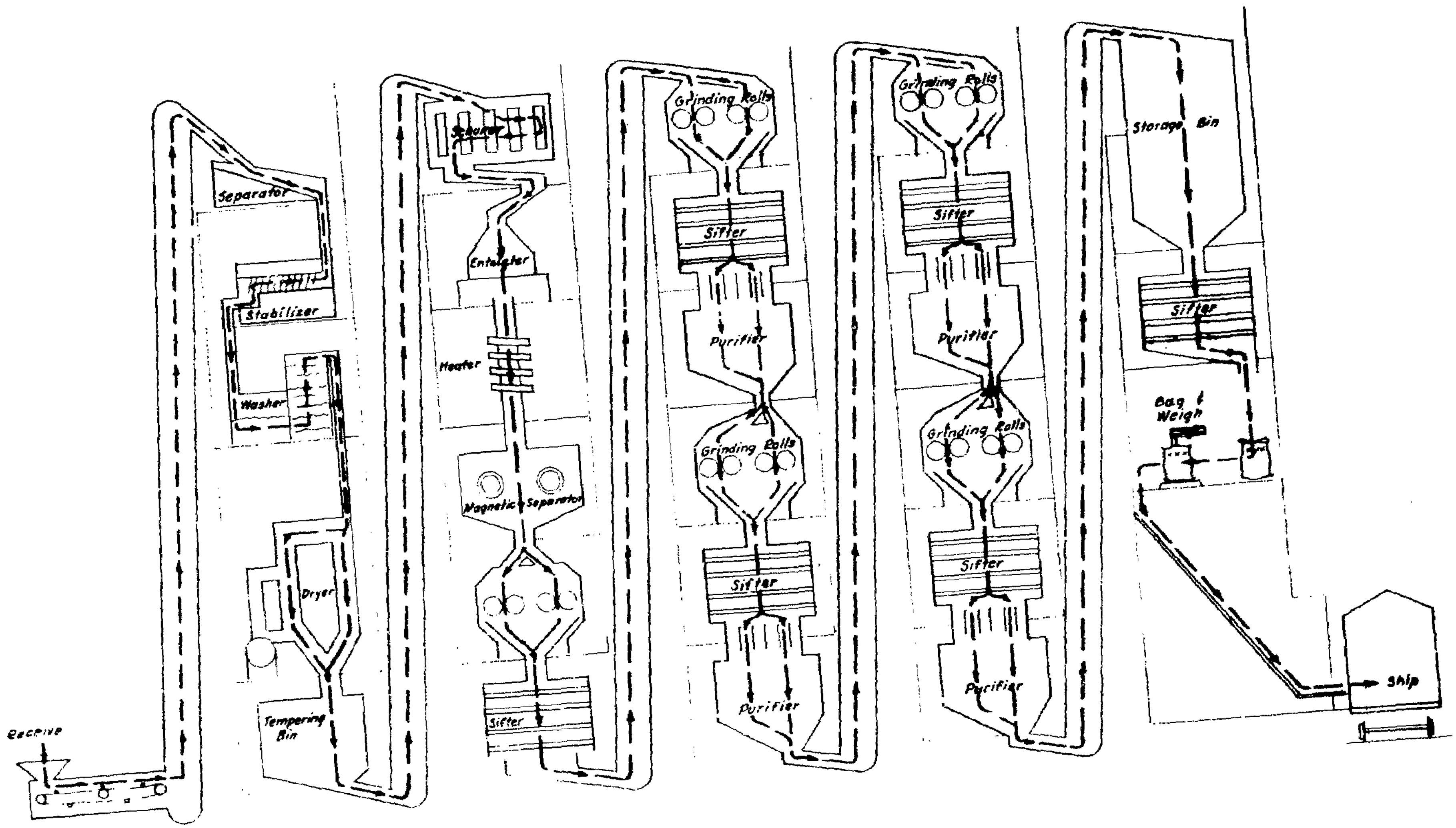


Figure 2-8 Simplified Diagram of Flour Process

of the various components of the wheat berry in the milling process. Thus, when the wheat is milled, it is possible to maintain the bran in large flakes the germ in small flakes and the endosperm in granules which may be ground into fine flour.

The milling process: grinding, sifting, and purifying

Grinding is accomplished by "chills", or heavy steel rollers, which revolve against each other in opposite directions, much like the old-fashioned wringer. They are mounted in pairs on roll stands. The results of grinding may be varied by changing the speed of the rollers, or by adjusting the distance between them, or both. There are two types of rolls: corrugated rolls, which initially break open the berry, and smooth rolls, which exert finer grinding action.

After each grinding, or "break", the stock is sifted through various combinations of wire sieves and silk screens - some 60 in all. The finest screens have almost 17,000 meshes to the square inch, which is ten times finer than the finest silk hose. The sieves remove the bran and fibrous portions of the berry, and then the pure flour is passed along to the screens. This operation, like grinding and purifying is repeated many times as the stock goes through the mill.

Purifying is essentially a grading operation. Like dry cleaning, both sifting action and air suction are employed to separate the chunks into several fractions according to size and weight. The results, called "middlings", are passed along to the smooth rolls for further processing. It should be emphasized that grinding and purifying are continuous processes, repeated over and over again, until the granules have been reduced to such a size that they may join flour of like fineness flowing continuously throughout the mill. The flow, of course, is accomplished in two ways: the elevators raise the material to the higher floors of the mill, and gravity then flows it down through the processing machinery.

Bleaching

After milling, unbleached flour has a yellowish cast and poor handling properties. Formerly, this was corrected by storing the wheat for several weeks, and permitting natural oxidation to bleach the flour. More recently, this process has been greatly speeded up by the use of chemical reagents, chiefly chlorine dioxide for cake flours and benzoyl peroxide for most other flours. Some flours yield best results when bleached, particularly cookie, cracker and pie crust flours.

Quality Control

Quality control is a continuous process conducted by the millers, laboratories, and even test bakeries and test kitchens. As has been noted, the milling process is a continuous one of gradual reduction of particulate sizes. A given particle, for example, may go through as many as 15 or 20 separate grinding operations. On the other hand, a small percentage of the "suction stock", resulting from purifying at the beginning of the process, may go directly into finished flour after one sifting. Because the milling process is a continuous one, inspection and quality control must also be conducted on a continual basis.

One method of control is simply to compare samples of wheat in process with control samples of given quality. The two samples are merely spread on pieces of sheet metal and visually inspected.

The company's central laboratories supplement the frequent inspections by the expert millers. From time to time, throughout the day, samples of flour and feed are sent to these laboratories, where they are analyzed for color, appearance, moisture content, protein, and ash. In addition, testing is conducted periodically in the test kitchen, as well as in the test bakery. The latter works under simulated commercial bakery conditions, while the test kitchens use regular household kitchen equipment to simulate conditions encountered in typical consumers' homes.

Packing

Packing is done under one of two general systems: "daylight" and "on-the-stream". The more modern method, daylight packing, makes use of bulk storage bins which can hold more than 24 hours worth of production. The packing itself is accomplished in less than 8 hours, on a continuous, non-stop basis. On-the-stream packing on the other hand, is conducted around the clock with finished flour being flowed directly to the packing machines under which packers fill and seal bags.

Both systems use paper and cotton bags, with weights designated by cwt. Each bag is stamped with a code which tells the date of packing, the grade, and other quality control data. The bags are then gravity fed, via chutes, directly to either the waiting cars or the warehouses.

Loading

The last step in the milling operation is loading.

Before loading, the cars are thoroughly checked for cleanliness and for absence of unpleasant odors which might affect the flour. If there is any evidence of contamination, the cars are thoroughly washed and/or vacuum cleaned. Precautions are also taken to insure the absence of weevil infestation and, if any such evidence exists, the cars are thoroughly fumigated.

Two types of freight cars are used. So-called "air slide" hopper-type cars are employed for bulk shipment of unsacked flour, and regular box cars accept the sack shipments. When the cars are fully loaded, the doors are closed and sealed with a tamper-proof seal to insure the arrival of the contents without theft, contamination or other damage.

2.2.3 Personnel

The personnel required to operate the plant under present-day conditions are listed below. This covers all operations from receiving wheat to shipping of the finished product.

Office	30
Engineering	10
Laboratory	20
Packaging & shipping	40
Storage of products	10
Milling process	40
Wheat cleaning	20
Storage elevator	30
Marine towers	15
Stevedores	15
Maintenance	50
Total	280

This mill usually operates three shifts per day, but may work less depending on how the grain supplies hold out or demand declines. However, because of the large storage facility, the normal personnel requirements change very little, making it possible to keep daily production reasonably steady throughout the year.

2.2.4 Shelter (within plant)

The flour mill has no shelter area, but consideration has been given to use of an inner basement area for this purpose. The protection factor has not been calculated, but the room appeared suitable for this use.

2.2.5 Shutdown and startup (normal)

Flour milling proceeds on a routine basis, and each operating unit tends to feed material into another unit or routes it to storage.

When the plant is shut down normally, the initial feed is stopped first and as each succeeding unit runs out of grain or flour, it is in turn shut down, until all machines are empty, stopped, and cleaned. It may take more than an hour to carry out all this routine, but it makes certain that all equipment is ready to be started up again as soon as needed.

To start up the plant, all units much be checked and ready for operation. Grain is fed into the first units of each process line and as the material passes to the next unit it is placed in operation. This continues on to the last machine in the milling process and the product is stored or shipped out of the plant.

2.2.6 Utilities (normal)

All water is obtained from the city mains which are well underground in this area because of the long, cold winters and the consequent frost level requirements. There are riser columns throughout the building with fire hoses at each floor level. Water is used extensively in washing and preparing the grain for milling, and this requires a fresh clean supply at all times.

Two sources of power are supplied. One obsolescent source is 25-cycle, but the connected capacity is about 900 HP. The other source is 60-cycle, and new equipment is being installed to replace the 25-cycle equipment as rapidly as the latter wears out through normal usage. About 650 HP has been installed to date. Eventually, the 25-cycle power source will be entirely eliminated.

2.2.7 Repair and maintenance capability (normal)

The plant has a good capacity for normal repair and overhaul work on the equipment used. However, under emergency conditions with many machines and much equipment damaged, outside help will be needed to carry out all the work involved.

Lathes, milling machines, drill presses, and welding machines are available in the plant for use in normal repair work, but if much equipment is to be reconditioned at any one time, it will be necessary to requisition some from other shops in order to handle the large amount of work. This means that the existing personnel in the plant can repair some machines, remove and replace others as they are sent out to and returned from outside service.

2.3 VULNERABILITY ANALYSIS

2.3.1 Low pressure blast range (0.0 psi to 1.5 psi)

The low range covers all disutility above the point where process equipment is so damaged as to require repair work that prevents continued operation.

The greatest effect of the blast over this range will be from flying debris, especially pieces of glass. At blast pressures near 0.1 psi, glass will start to break, and somewhere between 0.5 psi and 1.0 psi, practically all glass will be shattered and broken. At 1.5 psi, the glass will tend to fly as if driven in the force of a 50 mph wind. Glass could cut and pierce cloth material, break other glass and be highly dangerous to personnel. Glass will be scattered generally as the blast effect is felt, and the greatest damage will be in direct line, or path of progress, from windows and openings. Some sheet metal will also be torn off and blown into the buildings, but the damage from siding may not be as extensive as the damage from flying glass, especially inside the buildings. There should be very little shifting or moving of equipment. Outside walls will still be intact, and the effect on equipment inside will be similar to that of a 50-mph wind at worst, and will be reduced as the blast spreads out from the windows inside. On some floors, loose or light material will be tossed about, but damage will not be too extensive. Such items as sifter screens, sheet metal ducts or even elevator legs, if not well secured, may be moved or thrown out of place.

At 0.8 psi, some deformation of the conveyor bridge may take place. At higher pressures, this will increase although collapse will not take place until around 1.6 psi, which is above this low range. The damage will cause misalignment of equipment by bending frames, and may even cause some breakage as it approaches 1.5 psi, which will require repair in varying degrees over this range.

The sifter screens would probably receive some damage from missiles or from thermal radiation, with the severity of the latter depending on the direction of the blast. Since the sifters and their screens are located on the east side of the building, thermal radiation from that direction through the window would be especially damaging, and many or most of the screens could be destroyed. However, loss of all screens would not preclude processing of whole wheat flour (see section 2.4.4).

Piping and conduits should remain intact, but sheet metal ducts, air drying equipment and fan housing will be damaged by missiles. Following the blast, the air in the mill could be thick with dust, in the unlikely event that fires were to break out, they should be controlled very quickly to prevent explosions.

No major production delays should take place in this range of blast pressures.

2.3.2 Medium pressure blast range (1.5 psi to 3.5 psi)

The medium range begins where an appreciable amount of repair work becomes necessary to resume processing. The work involves replacement and repair of parts which can be done with the plant's existing facililities.

When overpressures exceed 1.5 psi, the siding will fail on the marine tower, leaving the equipment exposed. This could lead to some damage to equipment inside, but most of this is heavy, rugged machinery capable of withstanding the considerable amount of vibration and shock which accompanies ordinary operation; it should remain intact during this range and should be operable. The electric wiring and controls in the tower would be disturbed or damaged by the siding failure. The weigh scales may be damaged or out of balance. If empty, the large hoppers would be torn from their mountings; if more than half full, they may remain in a satisfactory condition.

The lateral bracing of the conveyor bridge is the weakest element in its construction because it will fail at 0.8 psi due to the ability of the siding to remain intact up to 1.6 psi overpressure. At 2.0 psi, the roof beams of the galleries and mill will fail, with resulting collapse of the roof on equipment below, as shown in figure 2-9. All conveyor equipment in the gallery will be badly mutilated, making it impossible to deliver grain to storage until the debris has been removed, and conveyor equipment repaired. In addition, above 2.5 psi and depending on blast direction, the blast pressures will cause the walls of the galleries to collapse and will add to the damage in the same area. A great deal of missile material--window glass, siding, loose or broken items-- will fly, hitting equipment and creating havoc and destruction.

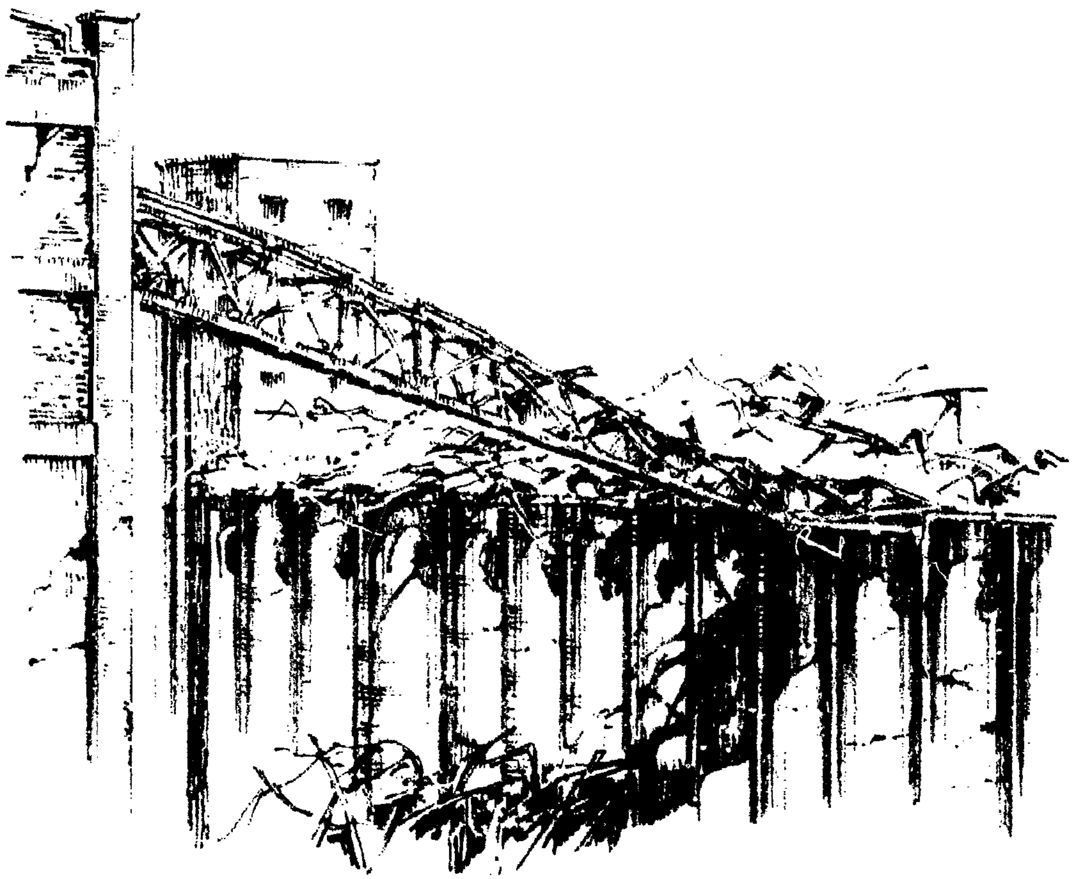
Some spare sifter screens, if stacked in line with windows, will be burned and destroyed over this range. The loss of all screens would be a serious bottleneck to continued operation.

The sifter units are wooden boxes about four feet square and six feet high, suspended from a framework near the ceiling. Four hardwood rods about one inch in diameter carry the complete weight of the units. A motor drive agitates the units in a short, circular motion to keep the material moving over the screens, sifting through as flour or passing over the screen to further operations. The unit would receive heavy shock loads under blast because with sides 4' x 6' or more, 1.5 psi totals two or three tons of pressure on a side. The plywood units are tough but under pressure will almost certainly fail, and repair will entail a considerable amount of carpentry work. Depending on direction of blast and distance from window openings, some machines may be usable and others completely destroyed. The units may be charred from thermal effects but will not be likely to burn from direct effects.

The purifiers are also vulnerable over this range and could be badly knocked about. Some dust and debris would be blown into the process area.

2.3.3 High pressure blast range (3.5 psi to 12.0 psi)

The high range begins where major structures fail and major equipment is damaged to the point where replacements are necessary or major repairs and



Damage to Corveyor Bridge at Flour Mill at 2.5 psi Overpressure

Figure 2-9

reconstruction are required. Repair work and time involved will delay process operation for a long period of time. This range ends at the point where plant failure is so extensive that repair is not economical and the plant should be abandoned or rebuilt.

The marine towers will overturn in the vicinity of 3.5 psi, and the south wall of the mill building will collapse at approximately 4.5 psi. These are major items in themselves, but what establishes the upper limit for the high pressure range is the crushing of bin walls, with collapse and complete failure somewhere near 12 psi; this appears to be the controlling point or limit for consideration of economical recovery.

The beginning of this new phase of major damage, the overturning of the marine towers, would probably require complete rebuilding of the units, as very little of the equipment or material would be expected to survive. The south wall of the mill building is subject to collapse around 4.5 psi, if the blast comes from the south.

Equipment inside the building, particularly that near the south wall, would be considerably damaged. Conveying equipment, grain cleaning and washing equipment and grain bins will probably be damaged or destroyed.

At 5.0 psi, the northwest storage bins, when half full or less will collapse, and the main bins, when half full or less, will begin to crack and be crushed. Figure 2-10 illustrates the damage at this level of overpressure.

At 10 psi, the mill building frame shows distortion with the collapse of the main bins at 12.0 psi and the mill building at 15.0 psi. The total facility would probably be beyond consideration for repair, and the total plant would be cleared away and rebuilt.

The rolls will receive some damage. They are heavy units, not easily shocked out of adjustment, but could be damaged by any massive solid material striking them with blast force. The chances are that many units will survive, being shielded by floors above and walls and other equipment around.

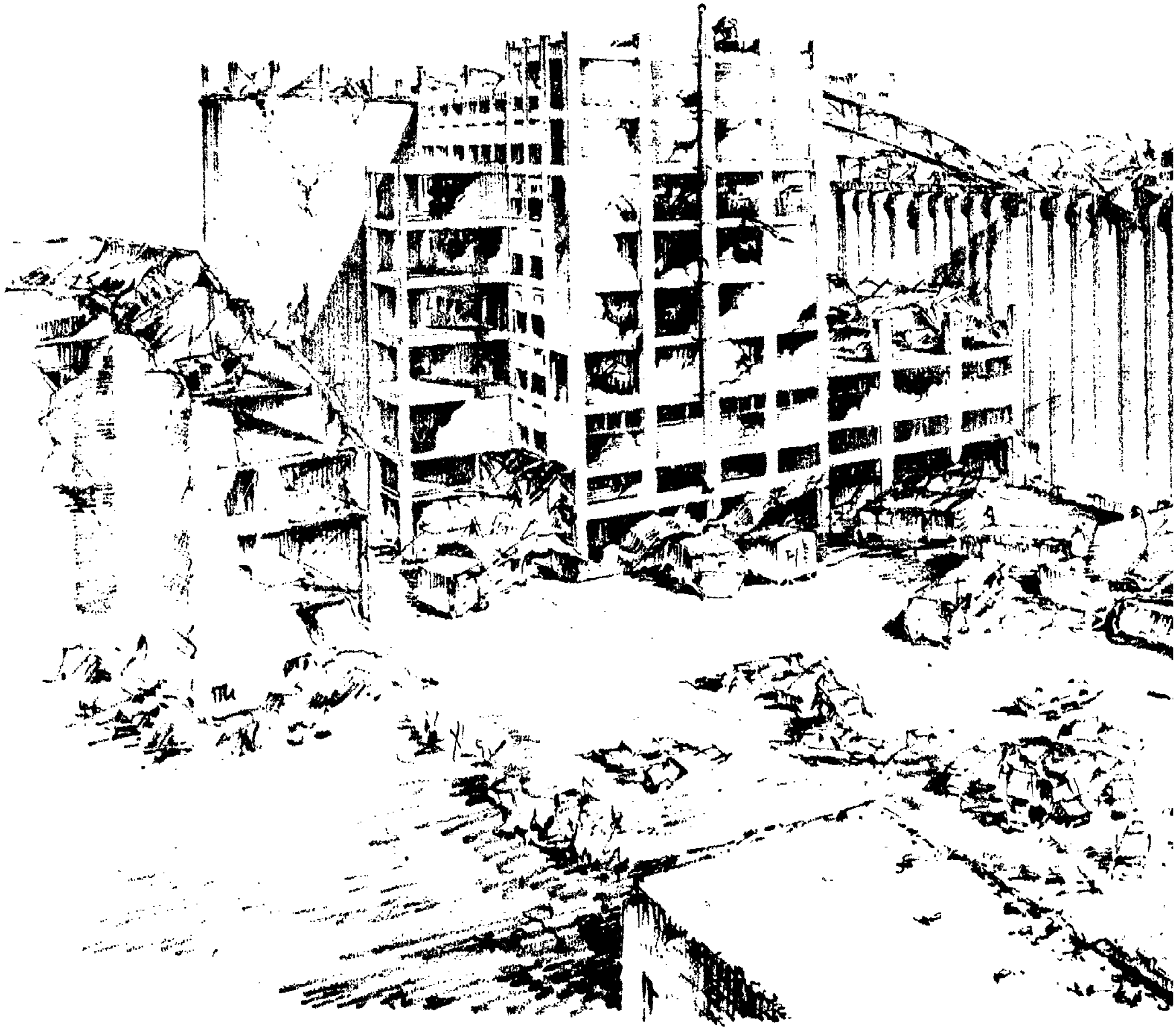
The packaging machinery, with its many small and moving parts, is easily damaged. However, this is generally located on the lower floors in well protected areas where its complete survival is possible.

In the lower part of this range, all material and equipment on the floor under the roof must be considered completely destroyed in all areas. Most elevating and conveying equipment will be destroyed in those areas, but the conveyors in basements will still be usable until the bins begin to collapse.

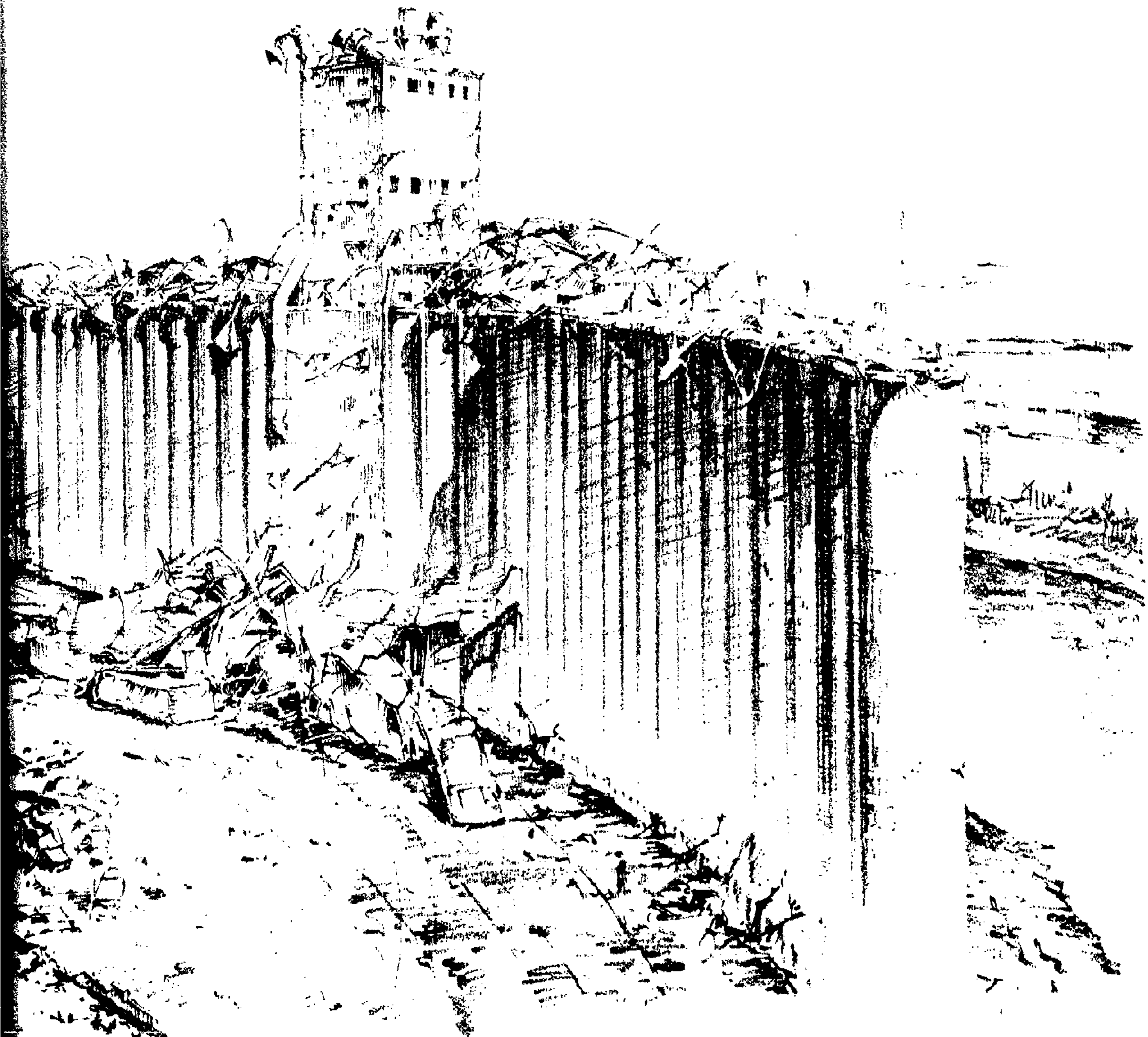
It may be generally concluded that at 3.5 psi the plant is still highly useful and can be repaired over a period of three to six months, but at a point between 10.0 and 12.0 psi, recovery is doubtful.

2.3.4 Thermal radiation

The thermal intensity could vary greatly within the high range: a 3.5 psi optimum burst from a 10 MT bomb would yield 50 cal/cm^2. The outside surface of the



Damage to F



age to Flour Mill at 5 psi Overpressure

Figure 2-10

mill is made entirely of either concrete, brick or corrugated sheet metal. These materials are not flammable, and the possibility of fires started on the buildings are therefore remote. But fires could be ignited inside the buildings where material may be in line with the fireball's radiation through windows and other openings. This ignited material in turn may be responsible for sparking dust explosions in the mill. The mill is very careful regarding dust accumulation in any area and has a dust collecting system to eliminate this hazard. Therefore, the likelihood of a dust explosion from thermal radiation or resultant fires appears remote. However, if these fires started by the thermal pulse should continue until the blast arrives, shaking the structure at the same time as the wind pours through the windows and openings, sufficient dust may permeate the air to provide an explosive condition. Further fires and explosions may result.

In any event, the thermal effect on screens, canvas connections and other exposed inflammable items would be extensive.

2.3.5 Fallout

Process materials in the flour mill would not be contaminated with radioactive fallout unless considerable damage had taken place first. The grain to be milled and the process equipment is always under cover so that fallout could not reach the flour unless large sections of the mill building were opened up. This only happens at higher damage levels when long delays are necessary to carry out repairs. The grain is carefully cleaned, washed and scrubbed to remove any dust before milling, and any fallout which happened to get in the grain would certainly be removed by these operations.

2.3.6 Shutdown

Normally, shutdown is initiated by closing off the flow of grain to the milling process, and each machine is stopped in turn as it runs out of feed material. This takes considerable time and could not be carried out in a rapid shutdown. All flow of material and operating machinery could be shut off at a moment's notice without any apparent damage, provided the shutdown does not last more than a week or so.

With a rapid shutdown, one problem throughout the entire plant is that material in the machines will continue to accumulate until the flow to each machine is individually shut off. This may block some operations temporarily and disturb the quality of output, but otherwise no harm is done over the course of a few days, although some machines will need checking and cleaning out.

If the shutdown should last over a longer period, then some damage may result, possibly in the grain cleaning area, and especially in the washing units. If these units are shut down quickly, grain may be left soaking in water and in various stages of the washing process. It will swell and become pasty and, if left long enough, the water may evaporate leaving the residue in a dried, caking block that would be difficult to remove. This would necessitate dismantling, cleaning out equipment, removing sludge and rust before beginning operation.

Some elevators and equipment may be plugged with grain or other milled material and this would have to be removed before each unit was started up again.

In general, however, no very serious damage will directly result from a fast shutdown. The more time that elapses after the shutdown, the more work involved in cleaning and preparing for operation again.

2.3.7 Bottlenecks and weak links

The conveyor bridge over which all wheat must pass from the storage elevator to the mill is very weak as compared to the rest of the plant. Even in the low damage range it would need some repair before operation would be satisfactory, and in the medium range it would have to be rebuilt.

The conveyor galleries near the roof will also be badly damaged during the medium range and would make the handling of wheat difficult or even impossible until repairs or replacements were made.

In the early stages of the high range the marine towers will overturn, making it impossible to unload any grain boats.

Lastly, the danger from explosive flour dust, described above in 2.3.4, should be noted.

2.4 RECOVERY

2.4.1 Summary of damage

The summaries of damage to structures and process equipment are shown in Tables 2-2 and 2-3.

2.4.2 Spare parts and cannibalization

The metal equipment is furnished by outside suppliers and manufacturers. A reasonable supply of parts is kept on hand for the usual repair and service requirements, but under major damage conditions many additional parts would be needed. They would have to be obtained from the manufacturers, who are scattered across this country and in some foreign countries as well. Under emergency conditions, then, cannibalization would be necessary. This could be carried out in International's mill or, possibly, arrangements could be made with other plants to exchange cannibalized equipment. Circumstances could be such that ships, as well as rails and trucks, could be used to advantage in transporting equipment.

Wooden equipment and parts can be repaired in the mill's own woodwork shop, as soon as radiation levels are low enough to permit personnel safely to do so. This equipment is presently repaired at the mill, and men could be available for this purpose, provided damage to the woodwork shop is minimal.

2.4.3 Initiating emergency operation

Following nuclear blast, a period of appraisal will be required to investigate damage and to determine what work is necessary to bring about complete recovery or, should this not be possible, plans may be formulated to operate under limited emergency conditions without complete recovery. Decisions will have to be made as to what equipment can be used with the least amount of repair and service, and repair priorities assigned on this basis.

The startup would require special consideration for each piece of equipment used in the process. A complete check should be made to remove foreign material and to see that the machine is unclogged, clean, and in condition to operate.

Then, assuming no serious blast damage, the milling process would be initiated by grain being fed to the cleaners, then to the washers. After cleaning, the grain should be conditioned for moisture content, and left in curing bins for eight hours before it can be fed to the rolls. From then on, the milling process can be continued and maintained as originally outlined in the discussion of operation and flow.

Conditions will be studied over each of the three blast damage ranges, and emergency operation will be discussed accordingly.

Table 2-2 Summary of Damage to Structures

Pressure psi	Conveyor Bridge	Marine Towers	Head House	Galleries	Receiving Hoppers	NW Bins	Main Bins	Mill Bldg.
0.1	Glass Cracking	Glass Cracking	Glass Cracking	Glass Cracking				Glass Cracking
0.5	Glazing Shattered	Glazing Shattered	Glazing Shattered	Glazing Shattered				Glazing Shattered
0.8	Top Lateral Truss Fails & Roofing Fails							
1.0						Empty Crushing Starts		
1.5		Siding Fails						
1.6	Collapse		Walls Cracking					
2.0				Roof & Frame Cracking		Empty Topple Over		
2.5				Walls Fail	Frame Fails	50% Full Crushing Starts		
2.8				Roof Slabs Break	Collapse			
3.0				Frame Collapse				
3.5		Overturn					Empty Collapse	
4.0								
4.5								South Wall Fails with South Blast
5.0						50% Full Collapse		
10.0								Frame Deformation
12.0							50% Full Collapse	
15.0								Frame Collapse

Table 2-3 Summary of Damage to Processing Equipment

Structural	Critical Overpressure (psi)	Processing Equipment
Glass cracking	.1	
Glazing shattered	.5	
Conveyor bridge: top lateral truss fails	.8	Conveyor misalignment.
Marine tower siding fails	1.5	Missile damage to control equip.
Headhouse walls cracking		Missile damage to control equip.
Conveyor bridge collapse	1.6	Conveyor equipment damaged.
Gallery roof beams fail	2.0	Conveyor equipment damaged. silk screens - missile and thermal damage. sifter units broken. canvas connections damaged. broken glass on equipment. sifter machines - support rods damaged. elevator legs broken - displaced. vertical sheet motor ducts to machines damaged. purifyers, glass and screen damage.
Walls of galleries fail	2.5	Conveyor equipment damaged.
NW bins (50% full) start crushing		Basement equipment damaged. Receiving hopper frames fail.
Gallery roof slabs break	2.8	Repair & replace conveyors. Receiving hoppers total collapse.
Gallery frames collapse	3.0	Replace equipment.
Marine towers overturn	3.5	Hoppers damaged - weigh scales broken, elevator bent, boom broken, power hoist damaged.
South wall mill building collapse	4.5	Damage to grain cleaner, washers, driers, conveying equip., tempering and blending apparatus.
NW bins (50% full) collapse	5.0	Equipment badly damaged.
Mill bldg. frame deformation	10.0	All equipment moved and damaged.
Main bins (50% full) collapse	12.0	All equipment badly damaged.

Operation following low blast damage (0.0 psi to 1.5 psi)

In the low blast damage range, very little structural failure takes place other than the shattering of glass and failure of some siding and roofing material. Some missile damage may occur in the mill building if silk screens are left exposed, and where there are glass windows to observe operation in the process machinery. This damage to the screens does not affect the rest of the machinery and, therefore, there should be very little delay in regard to the repair of process equipment.

The main problem over the low damage range is the accumulation of dust, dirt and debris in and around process equipment. Cleaning would involve removing all the wheat in process from the cleaning stage through the washers, as well as wheat in the rolls or sifters and other machinery, so that no foreign material might be present in the finished product. After a thorough check by the head miller, labor and tradesmen could be set to work cleaning and reparing all the equipment as required. Under the worst conditions this range may take no more than 1,000 man-days. Operation can begin as soon as machinery is cleaned, repaired and approved as satisfactory by the head miller. There is, however, the possible problem of fallout, which could delay repair until radiation dropped to levels that were safe for personnel in all work areas.

If electric power and water should be cut off, this would necessitate further delay, as there is no provision for emergency operation without these services being supplied from the outside.

Operation following medium blast damage (1.5 psi to 3.5 psi)

At the lower portion of this range, siding will fail on the marine towers, and walls will show cracking in the head house. These failures, in themselves, probably would not necessitate plans for emergency operation. When the conveyor bridge collapses, however, some delay will be necessary for repair, and if operation is to continue, some other means such as a portable conveyor, will have to be provided for conveying wheat from the storage elevator to the mill. Other means of conveying wheat would have to be supplied, either externally or internally, be means of new, improvised conveyor units. As gallery roof beams and walls fail, the necessity for additional replacement will increase considerably and, when their total collapse takes place near the end of this range, it will be necessary to supply some kind of external conveyor equipment.

Equipment in the mill building will require cleaning, repair and service, because of missile damage. After cleaning the equipment and replacing broken parts, the plant should be ready for operation. It is quite possible that during this range the damage to such items as silk sifting screens would be quite extensive, and the glass observation windows would be broken on most machines. Missiles, of course, may damage some machines and miss others. This could mean that through cannibalization of the machines and equipment on the floor, at least some of the units could be repaired and operated almost immediately.

Operation following high blast damage (3.5 psi to 12.0 psi)

Extensive collapse of structures and damage to equipment takes place over the high blast damage range, including destruction of the marine towers at lower limits of the range. The time necessary to repair and recover all of this facility would be considerable, although it might be possible to produce some emergency supplies of flour during this repair period through repair or cannibalization of a few units. But it seems unlikely that any flour other than whole wheat could be produced during the initial repair stages, with a minimum amount of rolling or grinding being provided. As repairs are carried out and equipment is replaced, refined flours can again be supplied in quantities as required.

Flour is usually kept in large storage bins at the mill for a period of seasoning, and this should be used as soon as possible to prevent any deterioration in the quality. This would take care of initial emergency conditions but would not last very long if new flour were not being milled continuously. Beyond this it would be necessary to resort to new flour made under various limited conditions, or even to the use of raw wheat itself.

2.4.4 Shortcuts

Under emergency conditions, a single type or grade of flour could be assigned to a mill, or to a group of mills that has sustained a similar level of damage. This would mean that flour of average consistency could be produced and delivered with the use of less machinery than is normally used, and that many machines could be left unserviced or unrepaired, while still maintaining production of flour. Many fancy, special grades could be dispensed with to allow for full concentration on bare essentials. For example, bread can be made from whole wheat ground without the use of sifters to eliminate the bran and coarse particles. Moreover, whole wheat is normally rich in vitamins which are removed in more elaborate milling operations and must, under law, be replaced artificially.

Raw wheat could be consumed as is, without grinding; well soaked and boiled, it is edible as porridge. This means that wheat could be removed from storage elevators and surplus stockpiles and supplied for use as is for as long as the supply or the demand lasts. As noted at the beginning of this chapter, the current supply could last as long as 3.7 years at the present rate of consumption. Barring a catastrophe of great magnitude, however, it should be feasible to transport the raw wheat to the nearest grain mill capable of processing it.

2.4.5 Utilities

Water supply

Since city water mains are located well underground, there would probably be no loss of water unless damage were very extensive, and at such blast levels the effects would be so damaging that the mill would not be in a position to use water. The riser columns throughout the building for fire hoses should remain intact and usable as long as the building is still standing. This means that water should be available even when the mill and process is not able to use it, and a shortage would not result unless the city water supply were cut off.

Electric power

The power lines supplying electricity to the plant are mounted on poles. These lines are susceptible to damage from flying debris, especially the falling of heavy material on wires as they enter or travel along the sides of buildings. Usually transmission lines themselves remain intact to 3.0 or 4.0 psi. Beyond this, the poles may collapse.

The transmission lines should remain intact through the low and medium blast pressure ranges and power should be available, provided the power supply is not damaged elsewhere. In all probability, power will be lost at the beginning of the high blast damage range, and would have to be replaced for service. However, the plant would not be in a position to use power for processing immediately after a blast in this range, and new lines and power could be established in time for use before the processing equipment could be repaired, replaced, and ready for operation.

2.4.6 Repair required to resume normal operation

Each range has damage conditions that are basically unique. For example, the low range has relatively little structural or process damage to delay production, the medium range has considerable structural damage which results in some process equipment damage with production delay necessary to carry out repairs, and the high range with major structural failures that cause major damage to process equipment and therefore considerable delays which prolong recovery.

Low pressure blast range (0.0 psi to 1.5 psi)

Fallout could be a problem at this or any level of blast overpressure, and the protection of personnel may necessitate shutdown for an indeterminate time. It might be possible for the operators to remain in sheltered locations such as the machine shops in the basement's maintenance area, until it is deemed safe for personnel to return to work.

Broken glass will present a cleanup problem. It will begin to crack in the vicinity of 0.1 psi. At 0.3 psi, perhaps half the windows will be shattered; at 0.5 psi, all of them. Some removal of glass and dust from the equipment and in-process grain and flour may prove necessary as the overpressure nears 0.5 psi.

Repair of the conveyor bridge, which will show damage to its structural members at 0.8 psi, will be necessary to establish original normal conditions. This work could be carried out with the conveyor operating, but under higher pressures equipment may be forced out of line and a shutdown period would be necessary for repair before normal operation could resume.

Over the low end of this range, most operations will require a shutdown period for cleanup. Following this, some additional repair may be necessary but, in general, normal operation can be established immediately following cleanup.

Medium pressure blast range (1.5 psi to 3.5 psi)

Siding fails, walls crack, roof beams collapse and a great deal of equipment damage takes place in the medium range necessitating considerable time and effort to initiate operation. Various parts of the mill will have to be shut down during rebuilding, repair and replacement. Through cannibalization, some portions may be made ready for operation sooner than others, and some production, such as processing whole wheat flours could be initiated at an early stage. But to resume normal operation, all work involving process equipment will have to be complete. Some structural work and finishing could be continued after normal operation is established. Thus, the time for resuming normal operation could be about half of the estimated time for work involved in complete repair. Cannibalization could allow some processes to start operating, but normal operation would not be established until all equipment was completely repaired. Some machines are manufactured and supplied from distant points, including foreign countries. Therefore, the time for complete recovery may vary considerably, depending on which units are damaged, and the time required to manufacture and ship their replacements.

High pressure blast range (3.5 psi to 12.0 psi)

At almost any point in this range some major structural failure takes place which adds to the repair and rebuilding requirements.

The overturning of the marine towers at 3.5 psi prohibits further grain unloading from boats unless other conveyors were used, and this would make unloading a long, tedious job. This still may be necessary until the marine towers are rebuilt or replaced.

The collapse of the south wall of the mill building affects the storage, cleaning and tempering area for wheat prior to the milling process. Wheat should be cleaned to remove any foreign material that might be damaging to milling equipment, it should be washed to purify and remove unhealthy material, and it should be tempered to help the milling process produce flour more efficiently. This equipment would need to be repaired or replaced before normal production can be attained.

The collapse of the northwest bins would not affect milling operations but would reduce the availability of wheat for milling use. Recovery would not be urgent for process operation, and construction could be delayed for other more important repairs, but reconstruction would eventually be necessary for complete recovery.

The deformation of the mill building would require considerable readjustment of equipment and probably repair or reconstruction of portions of the building to place equipment in satisfactory operating condition.

2.4.7 Substitutes

Flour is crushed by the use of rolls. This is the most efficient way to prepare the flour for separation from the bran. But adequate results can be obtained by grinding the wheat in feed mills or using a hammer mill to pulverize it. These units can be used to make good whole wheat flour and are used extensively for that purpose. They are used on the majority of farms for grinding animal feeds and would be in abundant supply in case of emergency. As a last resort, whole wheat could be ground in coffee grinders or, in the home, in blender-type appliances.

2.4.8 Increased production capability

The Buffalo plant of International Milling Company operates an 8-hour shift each day and maintains this schedule the year around. There are periods of increased demand when it is necessary to operate the mill on two and even three 8-hour shifts. This could be maintained through any emergency period to increase the supply to consumers during a postattack shortage. Since most mills operate on this basis, the milling industry has great potential for increased production capabilities nationally in times of crisis.

2.4.9 Estimated man-days required for repair for each level of blast pressure

These estimates will be found on the following charts. A graphical presentation of the required man-days of repair effort will be found in figure 2-11, following the repair estimates.

FLOUR MILL

Low Blast Damage Range 0 to 1.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
0.1	dust, dirt, debris cracking glass	clean up	labor	30	20	600
0.5	all glazing shattered	clean up glass replace glass	labor	5	20	100
0.8	conveyor bridge: top lateral truss fails and conveyor roofing fails	repair bridge and renew truss	tradesmen	20	20	400
			Structural			1100
	PROCESS					
0.1	dust, dirt, debris	clean machinery	labor	15	20	300
0.5	glazing shattered	clean all machinery and process equip. remove broken glass and repair	labor	25	20	500
0.8	conveyor roofing fails	clean and repair conveyor		5	20	100
	mill bldg. silk screens glass cut, etc.	check and clean screens, repair and rebuild damaged screens		25	20	500
			Process			1400
			Structural			1100
		Total Man-Days for Low Range				2500

Low Blast Damage Range 0 to 1.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
0.1	windows cracking	nil	--			
0.5	glazing shattered	clean up process equipment	labor	20	20	400
		repair missile damage to equipment	labor	25	20	500
0.8	conveyor bridge top truss fails	repair truss	tradesmen	5	20	100
		Total Minimum Man-Days Required for Low Range				1000

FLOUR MILL

Medium Blast Damage Range 1 5 to 3.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
1.5	siding on marine towers fail	new siding	tradesmen	5	100	500
1.6	head house walls crack	repair	tradesmen	3	100	300
	conveyor bridge collapse	clear away debris rebuild	labor tradesmen	8	100	800
2.0	gallery roof beams fail	clean up, repair and rebuild	labor tradesmen	10	100	1000
2.5	walls of galleries fail	rebuild walls	labor tradesmen	50	100	5000
	NW bins 50% full crushing starts	check damage and repair	labor tradesmen engineers	50	100	5000
2.8	gallery roof slabs break	rebuild roof	labor tradesmen	10	100	1000
3.0	gallery frames collapse	rebuild galleries	labor tradesmen	50	100	5000
			Structural			18,600

Medium Blast Damage Range 1.5 to 3.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS					
1.5	siding on marine towers fail	clean up, check missile damage new wiring and controls check scales and repair	labor tradesmen engineer	4	100	400
1.6	headhouse walls cracking and failing	clean equipment repair wiring controls. motor drive units, etc.	labor tradesmen	4	100	400
	conveyor bridge collapse	repair or replace all equipment	labor tradesmen	8	100	800
2.0	gallery roof beams fail	clean and repair all conveyor equip.	labor tradesmen	4	100	400
	silk screens: thermal burns missile damage	check screens repair or replace	head miller laborers	7	100	700
	sifter units broken	repair or replace	labor tradesmen	8	100	800
	canvas connection damaged	replace	carpenters & laborers 50% each	4	100	400
	broken glass on equipment	replace	labor	2	100	200
	sifter machines damaged - support rods broken	replace rods etc.	labor tradesmen	4	100	400
	elevator legs broken out of place	repair and replace	labor tradesmen	8	100	800
	sheet metal ducts vertically between machines & floor	repair and replace	labor tradesmen	6	100	600
	purifiers glass and screen damage	new glass - screens repair & replace	head miller carpenters laborers	8	100	800

FLOUR MILL

Medium Blast Damage Range 1.5 to 3.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS (Cont'd)					
2.5	receiving hoppers frame fails	repair	labor tradesmen	10	100	1000
	walls of galleries fail	clean, check & repair conveyor equipment	labor tradesmen	5	100	500
	NW bins 59% full crushing	clean, check & repair equip.	labor tradesmen	5	100	500
2.8	gallery roof slabs break	clean, repair & replace equipment	labor tradesmen	10	100	1000
	receiving hopper total collapse	rebuild hoppers	labor tradesmen	10	100	1000
3.0	gallery frames collapse	clean equipment repair and replace	labor tradesmen	5	100	500
			Process			11,200
			Structural			18,600
		Total for 1.5 to 3.5 psi				29,800
		Total for Low Range				2,500
		Total for Low & Med. Ranges				32,300

Medium Blast Damage Range 1.5 to 3.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
1.5	siding on marine towers fail	check and repair missile damage	tradesmen	4	50	200
1.6	bridge conveyor collapse	repair and rebuild bridge and equipment	tradesmen	4	50	200
2.0	gallery roofbeams fail	check for safety and repair equip.				
		check: silk screens glass on sifters, etc. missile damage throughout	tradesmen	10	50	500
2.5	receiving hoppers frame fails	repair frame	tradesmen	4	50	200
	walls of galleries fail	clean up rubble repair equip.	labor tradesmen	4	50	200
	NW bins 50% full crushing	check for safety repair	tradesmen	4	50	200
2.8	gallery roof slabs breaking	check for safety - clean & repair equip.	labor tradesmen	6	50	300
	receiving hopper collapse	repair or rebuild	--	4	50	200
3.0	gallery frames collapse	repair galleries repair equip.	labor tradesmen	20	50	1000
		Minimum Man-Days Required for 1.5 to 3.5 psi				3000
		Minimum Man-Days Required for Low Range				1000
		Total Minimum Man-Days Required for Med. Range				4000

FLOUR MILL

High Blast Damage Range 3.5 to 12.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
3.5	marine towers overturn	clear away debris, rebuild and replace marine towers	labor tradesmen technicians engineer	25	200	5000
4.5	south wall mill building collapse	clean up rubble rebuild wall	labor tradesmen engineer	40	200	8000
5.0	NW bins 50% full collapse	rebuild bins	contractor: labor tradesmen engineer	200	200	40,000
10.0	mill bldg. frame deformation	repair frame repair and rebuild all walls	contractor: labor tradesmen engineer	100	200	20,000
			Structural			73,000
	NOTE: At or above 12.0 psi it is uneconomical to repair plant					
12.0	main bins 50% full collapse					
15.0	mill bldg. collapse					

High Blast Damage Range 3.5 to 12.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS					
3.5	marine towers overturn. hoppers collapse. scales broken	rebuild hoppers replace weigh scales	labor tradesmen technicians engineer			
	elevator bent boom broken power hoists broken	rebuild elevator rebuild boom rebuild or replace		25	200	5000
4.5	mill bldg. damaged grain cleaners grain washers grain conveyors other equipment	repair or replace " " " " " " " "	labor tradesmen technicians	50	200	10,000
5.0	NW bins 50% full collapse	repair and replace all equipment	labor tradesmen technicians	50	200	10,000
10.0	mill bldg. frame deformation	repair and replace all equipment	labor tradesmen technicians engineer	100	200	20,000
			Process			45,000
			Structural			73,000
		Total for 3.5 to 12.0 psi				118,000
		Total for Medium Range				32,300
		Total for High Range				150,300
12.0	main bins 50% full collapse					
15.0	mill bldg. collapse					

FLOUR MILL

High Blast Damage Range 3.5 to 12.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
3.5	marine towers overturn	cannabalize repair and rebuild one tower	labor tradesmen technicians engineer	40	100	4000
4.5	south wall mill bldg. collapse	clear away rubble. repair & cannabalize equipment	labor tradesmen technicians engineer	30	100	3000
5.0	NW bins collapse	provide means of removing wheat	labor tradesmen engineer	20	100	2000
10.0	mill bldg. frame distortion	repair building repair and cannabalize machinery	labor tradesmen engineer	50	100	5000
		Minimum Man-Days required for 3.5 to 12.0 psi				14,000
		Minimum Man-Days required for Med. Range				4,000
		Total Minimum Man-Days required for High Range				18,000

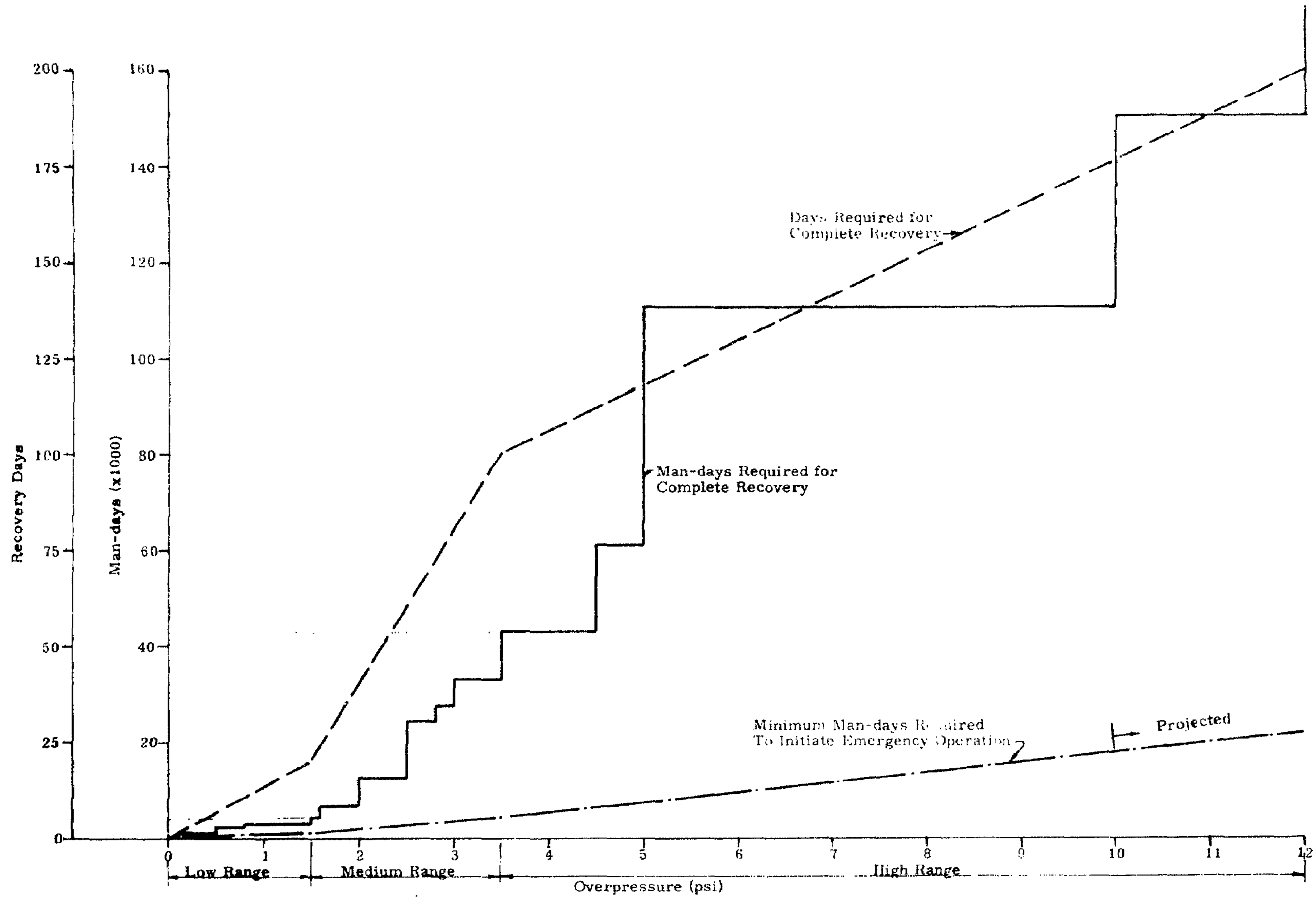


Figure 2-11 Recovery Chart - Flour Mill

2.5 CONCLUSIONS

The International Milling Company plant in Buffalo, New York is a very stable structure, and should remain so, even under excessive blast conditions. Buildings and equipment are very well made and as observed, failures involving extensive delays in production are generally in the higher ranges of blast. With mills scattered so widely over the nation, it is difficult to conceive of shortage except under the most extreme attack patterns. Since wheat is edible in any form from raw wheat to the finest quality of flour produced, and large surplus stocks exist, there is ample reason to believe the nourishment in some grade or condition can be supplied by this or other mills at all times, or without any mills whatsoever.

The mill building would sustain less damage at 4.5 psi if the south wall had more window area to ease the pressure. This would prevent bricks from falling and damaging equipment before frame deformation takes place at 10.0 psi.

The conveyor bridge should be strengthened or hardened to sustain a higher blast pressure, so as to raise its failure point to a level closer to that of the other structures. This would prevent a loss of wheat delivery to the mill when all other facilities are capable of operation and production.

The man-days required for recovery are relatively high, due to the size and massiveness of the structures and facilities to be repaired or replaced.

In the low range, most of the work involved consists of cleaning to remove foreign material from the process material as a minimum requirement to initiate operation. After the plant is in operation, all debris can be removed, glass and siding replaced to bring the plant back to normal.

The medium range requires some structural repair first as well as cleanup and this can be followed by repair of equipment. Production can be initiated while structural repairs are being completed.

In the high range, a great deal of debris cleanup is required first. The construction of new buildings and repair to damaged structures would have to be generally completed before machinery could be placed. Repair of machinery and replacement with new equipment would follow as soon as mounting locations are provided.

3. YEAST INDUSTRY

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3. YEAST INDUSTRY

3.1 A REVIEW OF THE INDUSTRY

3.1.1 General

In comparison with the other segments of the food industry covered in this report, the yeast business is a relatively small one in terms both of dollar volume and production. According to the 1958 Census of Manufacturers, total production in that year amounted to approximately 263 million pounds.

Yet yeast is of great value, because of its ability to cause fermentation when present in solutions of carbohydrates. As a result, the carbohydrates are broken down into ethyl alcohol and carbon dioxide. Yeast is therefore used in producing wine from grape juice, cider from apple juice, and beer from sprouted barley, as well as grain alcohol.

A similar process occurs in breadmaking. Yeast plants, mixed with starch and in the form of yeast cakes, are mixed in the dough; immediately the yeast acts on the starch present, producing first glucose, then alcohol and carbon dioxide. Lastly, the dough is kneaded and baked. Kneading serves to break up the bubbles of carbon dioxide which form and are the cause of many small holes present in raised bread. Any alcohol present is driven off in the baking process.

Yeast is a one-celled fungus widely distributed in nature. Most compressed yeast is produced in commercial sizes, and sold to bakeries for use as an ingredient. These uses accounted for 257 million pounds, with a value of $46 million. A small amount of yeast is packed for consumer use in the home, in 2-ounce sizes, and the 1958 consumer volume was only 6 million pounds.[20]

The role of yeast as a vital concomitant of the flour and baking industries is obvious. In the postattack context, a second reason for close study of this industry is its vulnerability due to the limited number of plants. There are only 16 compressed yeast plants in the United States, and most of them are located in large metropolitan markets.[17]

Dry yeast

Dry yeast, in flake form, can be shipped without refrigeration. Water is added and reconstituted yeast produced as required. This product has the advantage of not requiring refrigeration during transportation but the disadvantage of requiring time to prepare for use again. It will keep for one year at ordinary temperatures and for five years if refrigerated. It appears that if large quantities of yeast were required for emergency conditions, this could be a satisfactory way to stockpile it, ready for use. This subject may merit further investigation.

3.1.2 Geographical locations

The map of the compressed yeast plants in the United States, figure 3-1, shows that they are concentrated in a few population centers: New York, Chicago, St. Louis, Dallas, New Orleans, San Francisco, and Seattle. These markets are also centers for the yeast industry's chief customer, the baking industry. The number of plants producing compressed yeast is only 16, and these are owned by only 7 companies: Standard Brands, Anheuser Busch, Federal Yeast Corp., Red Star Yeast and Products Company, National Yeast Corp., Capital Yeast Company, and Atlantic Yeast Company.

There are other forms of yeast, such as brewer's yeast, which have not been considered in depth in this study because they do not directly relate to food production.

3.1.3 Sources of supply

Yeast is produced principally from molasses, which is available in large quantities as a byproduct of sugar refining (see section 4.2.2). Supplies come from the sugar plants located in the cane growing areas and near sugar beet fields. Molasses is generally shipped by tank barges or by railroad tank cars, depending on the location and economy of the operation. Yeast can also be produced using various grains such as wheat, rye and barley, as well as potatoes, but commercially it is more economical to use molasses.

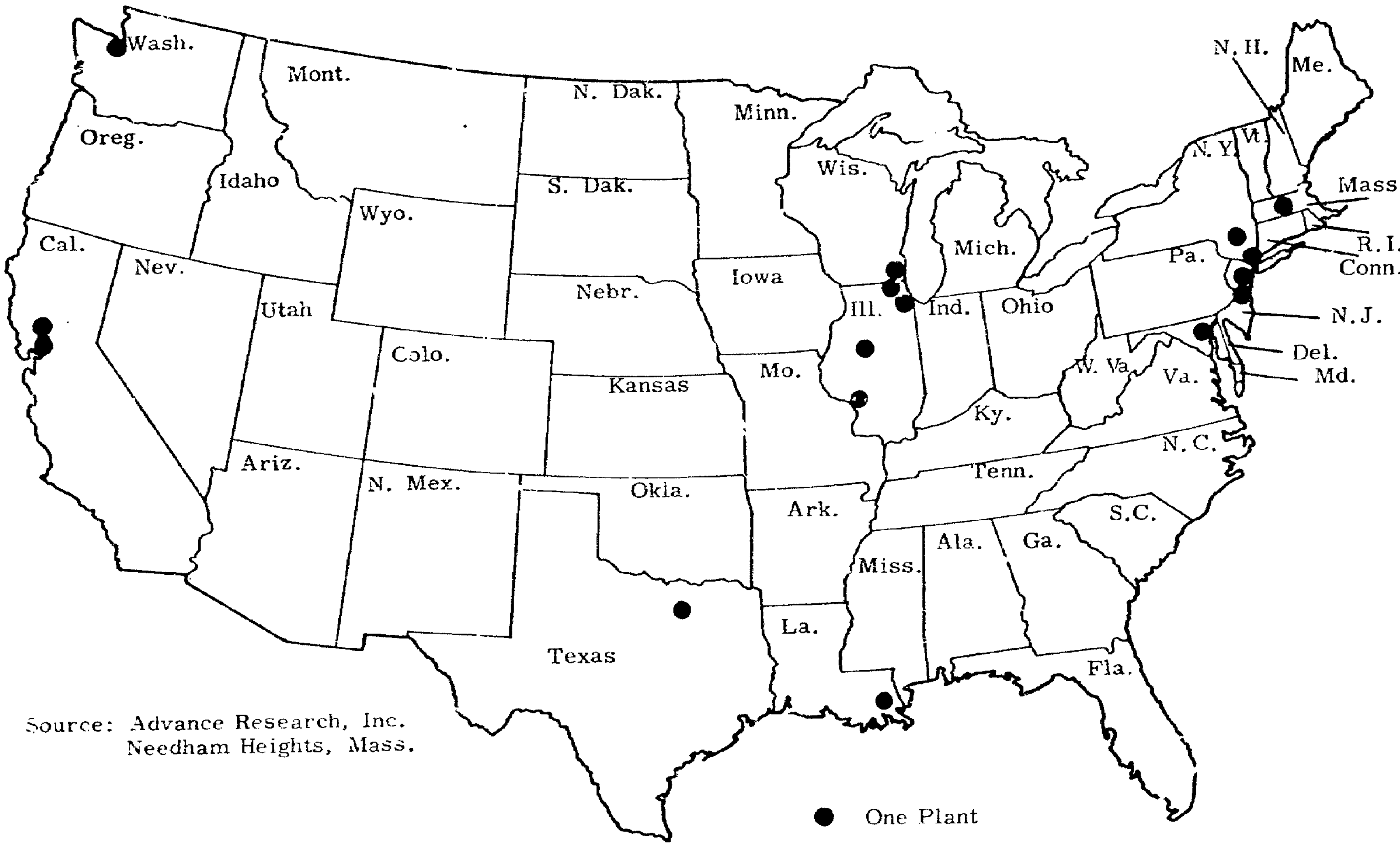
3.1.4 Transportation

Shipments of molasses are usually received at the yeast plant by rail in tank cars. Tank trucks are also used but to a limited extent.

Shipments of yeast out of the plant, on the other hand, are made almost entirely by refrigerated trucks, although shipments can also be made by refrigerated railroad cars. Yeast cannot be left without refrigeration for more than three or four hours at average temperatures, or it will begin to deteriorate. Therefore, refrigeration of long hauls is an absolute necessity. Short hauls or small deliveries can be made without refrigerated trucks, if the elapsed time is sufficiently short. Dry yeast, described above, is not generally used.

3.1.5 Trends

Probably due to its small size, there are very few data available on the yeast industry, and many of those which are available date back to 1958.[21] However, it is self-evident that compressed yeast is directly tied in with the uses of grain, and particularly with the baking industry. The study of the Flour Industry (see section 2.1.1) shows that wheat production has remained static, with the declining per capita consumption being compensated by the increase in population. It would therefore seem safe to assume that the compressed yeast industry is in a correspondingly non-growth position. The extremely small number of yeast plants reflects this.



Source: Advance Research, Inc.
Needham Heights, Mass.

Figure 3-1 Compressed Yeast Plants, 1961

3.2 YEAST PROCESSING PLANT

3.2.1 General description

A discussion of the phases in yeast production, in order of general operation, follows.

The yeast plant studied is in the Middle West, and was built in 1925 of combination steel and wood frames with brick walls, as shown in figure 3-2. The three principal areas are the yeasthouse, the boilerhouse, and the engineroom. Other plant equipment includes the stack, water tower, and the molasses storage tanks in the yard. There is a steel bridge between the power house and the engineroom.

Yeast house

The yeasthouse is a steel frame, 4-story structure with 13-inch brick walls and 26-60% window area. Floors and roofs are reinforced concrete slabs on steel beams. It is heavier-than-normal industrial construction.

Boilerhouse

The boilerhouse is 50 feet high, 53 feet wide, 88 feet long. It has a steel frame with 8-inch brick walls, except for the upper portion of the end wall which is 22 gauge metal siding. The lower portion of the walls has over 25% window area.

Engineroom

This is a separate building, but it adjoins the yeasthouse on one side. It measures 67 feet by 120 feet by 22 feet high. It has a precast concrete roof on steel purlins, steel columns and beams, and 12-inch brick walls with an average of 50% window area.

Stack

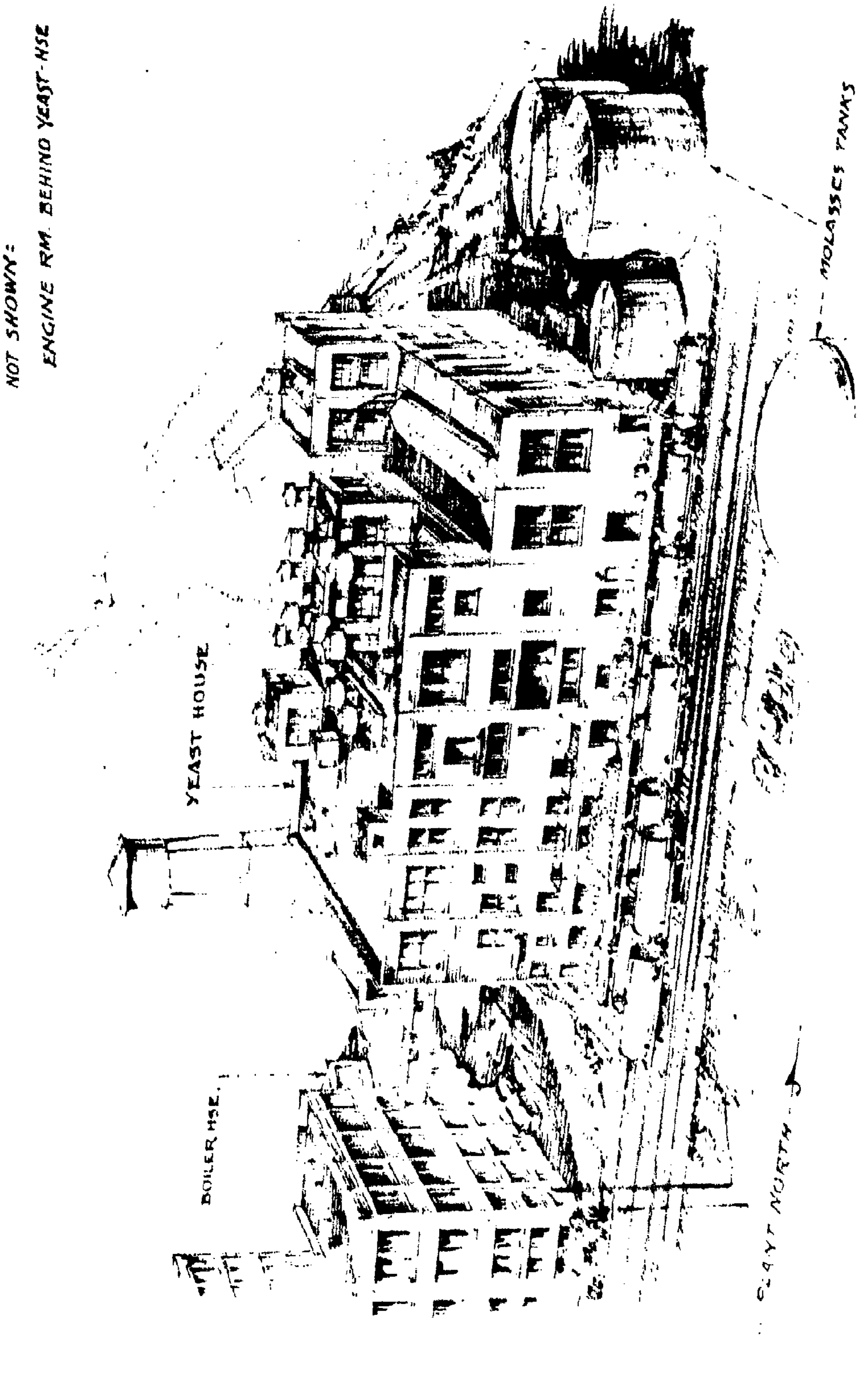
The single stack, adjoining the boilerhouse, is of reinforced concrete, 207 feet high. The base is 17 feet in diameter and 11-1/4 inches thick. The top is 12 feet in diameter and 6 inches thick. The chimney has 6-inch brick lining for 50 feet of height.

Water tower

The tank has a capacity of 100,000 gallons and is supported on a four-legged tower 87 feet high. The tower columns at the base form a 30-foot square.

Plant storage

The large, circular outdoor storage tanks are supported on foundations at ground level and connect with the plant via piping through an underground tunnel. The underground tunnel is used mainly to protect the pipes as they pass under the railroad tracks. Pumps in the basement of the plant supply molasses as required for processing. Usually, a sufficient quantity of molasses is kept in storage to keep the plant in operation from 4 to 6 months.



Yeast Factory

Figure 3-2

3.2.2 Operation

A flow chart is shown in figure 3-3.

Molasses scale tank

Molasses is first delivered to a scale tank for weighing and determining specific gravity. Adjustments are made to correct the concentration of the molasses, in order to standardize the texture of the material used.

Treating room

Here the molasses is treated and checked in the laboratory by the operators until the correct consistency is obtained. Treating tanks are used to supply the necessary additives to each tank until tests indicate the mix is correct and ready to be used for the fermentation process.

Filter press room

The mix is then filtered to remove any foreign material that might impair the quality of the yeast. The filtering takes place as the molasses flows from the treating room on its way to the zulauf room. This prepares the mixture for the zulauf machine.

Zulauf room

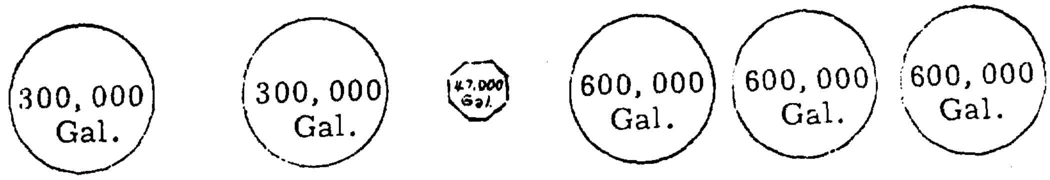
Here the material is held in tanks and fed to the fermenting tanks. The zulauf equipment supplies the right amount of material to each fermentation tank as and when required. The yeast starter is introduced first and then molasses and other materials are introduced to produce the maximum yeast growth in a minimum time for a quality product.

Fermenter tanks

Yeast starter (or yeast plants) is supplied to each tank to start the growth process. Then new material is added for this growth to feed on, in a continuous operation that supplies new material fast enough to keep the growing process progressing smoothly and efficiently. A continuous supply of air is also fed into the bottom of each tank and out the vent stack to aid the growing process. After sufficient time has elapsed for the growth to be complete, usually several days, material is drawn off as needed. The process in each tank is usually arranged so that tanks are successively ready for use to maintain a smooth, continuous supply for the remainder of the process and for shipping. The material is drawn off by means of pumps which supply the next operation as required.

Separator

Material, as pumped from the fermenter tanks, is supplied to the separator tanks. The operators here check and test the material in the laboratory nearby. The material passes through the centrifugal separators to remove and drain off liquid materials. The yeast is then removed and passed on to the yeast receiver room.



1. MOLASSES STORAGE TANKS
   5 to 6 Molasses Supply

2. SCALE TANK

3. TREATING ROOM
   Consistency
   Correction

4. FILTER PRESS ROOM
   Filtration

5. ZULAUF ROOM
   Material Held in Tanks
   and Fed to Fermenting
   Tanks as Required

6. FERMENTER TANKS
   Yeast Starter Supplied
   to each Tank. Air
   fed into Lower Part of
   Tank. Yeast drawn off
   by Pumps.

7. SEPARATOR

   Removes Liquid and
   Wastes it away thru Drains

8. RECEIVER ROOM
   5 Large Tanks

9. PRESS ROOM
   Filter Presses remove
   more Liquid from Product

10. CUTTING & WRAPPING ROOM
    Packing Equipment

11. STORAGE
    Refrigerated Storage
    Space.

12. SHIPPING

Figure 3-3 Flow Chart of Yeast Factory

Yeast receiver room

Here the yeast is received in five large tanks where it is held as a continuous supply for the pressing operation.

Yeast press room

The yeast is drawn from the receiver room and placed in tanks with cloth containers. Pressure is applied squeezing out any excess moisture that remains, leaving only the yeast -- ready for packaging, refrigeration and shipping.

Cutting and wrapping room

The yeast from the press room is delivered in lumps that vary from approximately one pound to perhaps five pounds in size. These are then cut and trimmed for various packages: five pound packages, one pound packages, and some very small units of less than one ounce. They are wrapped and placed in cartons for handling purposes.

There is a considerable amount of heavy equipment used for this purpose which could withstand rough treatment without undue damage from direct blast, but secondary damage could result from building failure. If this equipment were damaged, other containers could be used in which to place the yeast for refrigeration. Manual labor could be used if necessary.

Storage

After packaging, the cartons are conveyed to the refrigeration room for cold storage, where they are stacked ready for shipping. It is necessary to keep the yeast refrigerated at all times to preserve its quality.

Shipping

All shipments are made in refrigerated railroad cars and truck units.

Shipment could be made at almost any stage after delivery from the fermentation tanks. Each successive stage following this is just added refinement that has become necessary to meet special customer requirements and the competition. Shipments could be made over short distances without refrigeration, but beyond a certain point, particularly in warm weather, the quality would deteriorate quickly. Therefore, to assure quality delivery, refrigeration is always used.

3.2.3 Personnel

The fermentation process is continuous in the fermenter tanks. The compressed air and steam heat requirements must be available continuously, making it necessary for some operators to remain on duty at all times to make sure this continues uninterrupted. The remainder of the process can be carried out in a normal eight hour shift.

Office	15
Packaging	20
Shipping & storage	20
Process operators	40
Steam plant and Engineroom	20
Maintenance	40
Total	155

3.2.4 Shelter (within plant)

The yeast plant had no provisions or plans made for a fallout shelter, and no consideration was indicated regarding shutdown procedure in case of an emergency of this kind.

Some protection could be found in the basement area, but with excavation and construction a much better place could be provided.

3.2.5 Shutdown and startup (normal)

Under normal operating conditions, the plant is shut down by completing all process operations and leaving all units empty. It may take several days for the fermenter tanks to complete the cycle of yeast growth before the tank is empty. As each tank is emptied, it is thoroughly washed and sterilized. All pipelines and processing equipment are also thoroughly cleaned as a final operation. After each unit is emptied and cleaned, it is ready for startup.

The startup of the plant is initiated by feeding molasses through the proper equipment for filtering and mixing, and then feeding it into the large fermenter tanks. Compressors pump air into the tanks to help the yeast grow. After three or four days, the yeast has reached the proper growth stage and the contents are ready for removal, to be processed and packaged. Each piece of equipment is normally started up as it is needed in the process.

3.2.6 Utilities (normal)

Steam supply

A steam boiler plant is operated to supply and maintain necessary temperatures for proper functioning throughout the plant and to furnish steam for the turbines used for power to drive the air compressors. There are several large hot water tanks to supply the necessary hot water for washing and purifying each tank as it is emptied of its contents and before a new batch operation is started. This is a very important part of the work involved in plant operation to maintain purity of product and prevent any foreign fungi or plant growth to develop in any part of the process. A considerable amount of compressed air is required and compressors are run by steam turbines. It is necessary to force air into the bottom of the fermentation tanks in a slow continuously distributed manner to assist the yeast growth.

Water supply

Water is required for the processing of yeast to provide the correct consistency, for boiler feed water, and for the fire sprinkler system. A chlorinating house is provided and all water passes through it for chlorination before being used in the plant. Two large hot water tanks are located on the third floor for the purpose of washing all tanks and equipment as required, to keep it free of foreign materials and plant growth in the process.

Three systems are used:

1. Loop system consisting of a 6-inch pipeline surrounding the plant area connected to six 200-feet-deep wells.

2. Deep well supply. These wells are in addition to those in the loop system and are controlled by non-automatic electric deep well pump units as follows:

#27	1,000 gal. per minute
#28	1,000 gal. per minute
#30	1,000 gal. per minute
#31	1,500 gal. per minute
# 7	1,000 gal. per minute
# 5	1,000 gal. per minute

3. City water supply:

   - 12 inch City Water Main - direct pump system at 61 lbs. pressure from Pekin Waterworks, 600 feet away and along Highway 29 at the east side of the plant.
   - 8 inch tie to plant from above line
   - 4 inch branches around plant
   - 6 inch tie to another 12 inch City Water Main on north side of plant

In case of fire, there is a sprinkler system throughout the plant, supplied by a 100,000 gallon steel tank with the bottom of the tank ten feet above the highest sprinklers.

Electric power

Electric power is supplied to the area by Central Illinois Light Company. There are three 200 KVA transformers on a concrete platform, fenced in for protection. All power received is by means of overhead transmission lines.

Tanks

For the most part, tanks are made from 12 gauge copper or stainless steel, with a few as light as 18 gauge.

Molasses storage tanks

3	- 60,000 gal.	1,800,000
2	- 300,000 gal.	600,000
1	- 47,000 gal.	47,000
		2,447,000 gal.

Sulphuric Acid

1	- 8,000 gal.	
1	- 6,300 gal.	14,300 gal.

Ammonia tanks (for refrigeration)

3	- 20,000 gal.	60,000 gal.
2	Ammonia brine cooling tanks	
	Ammonia condensers	

Oil House 22' x 33'
Attached to the engineroom

Fermenter tanks
12 tanks 18' diameter x 2 stories

3.2.7 Repair and maintenance capability (normal)

The plant has a general repair shop which is equipped with heavy duty tools such as a shaper, lathe, welding equipment, drill press and many hand tools with which the usual plant maintenance and repair is done.

Plants generally do not retain a large staff of personnel trained in the operation of such machines and tools, because the time spent in their operation is nominal. Therefore, in the event of major damage to the plant, much of the repair work would have to be done by outside shops or personnel brought to the plant to augment the plant maintenance crew.

It appears that the repair facilities are adequate to make the processing equipment operative under emergency conditions, following blast damage in the low and medium ranges. In the high range of damage, additional outside assistance would be required to repair the equipment for emergency use.

3.3 VULNERABILITY ANALYSIS

3.3.1 Low pressure blast range (0.0 psi to 2.5 psi)

Within this range the greatest damage will be due to dust, dirt and missiles.

At a pressure of 0.1 psi, glass will start to crack. As the pressure increases from 0.5 to 1.0 psi, all windows and glass will be shattered and broken, and missile damage will be generally extensive.

Near 1.0 psi, siding from the boilerhouse will be torn off and, together with flying glass, will severely damage glass gauges, meters, control panels and other fragile equipment. During this range, loose or light material may be tossed about; however, very little shifting or moving of the equipment will occur.

Most of the equipment throughout the plant such as tanks, vats, press units and packaging machines are fabricated of heavy material and will not be damaged, although the molasses storage tanks, if empty, will receive considerable damage in this range. At 1.0 psi, the empty tanks will show cracking of the sides, and at 2.5 psi, severe deformation would occur, accompanied by increased cracking.

3.3.2 Medium pressure blast range (2.5 psi to 5.5 psi)

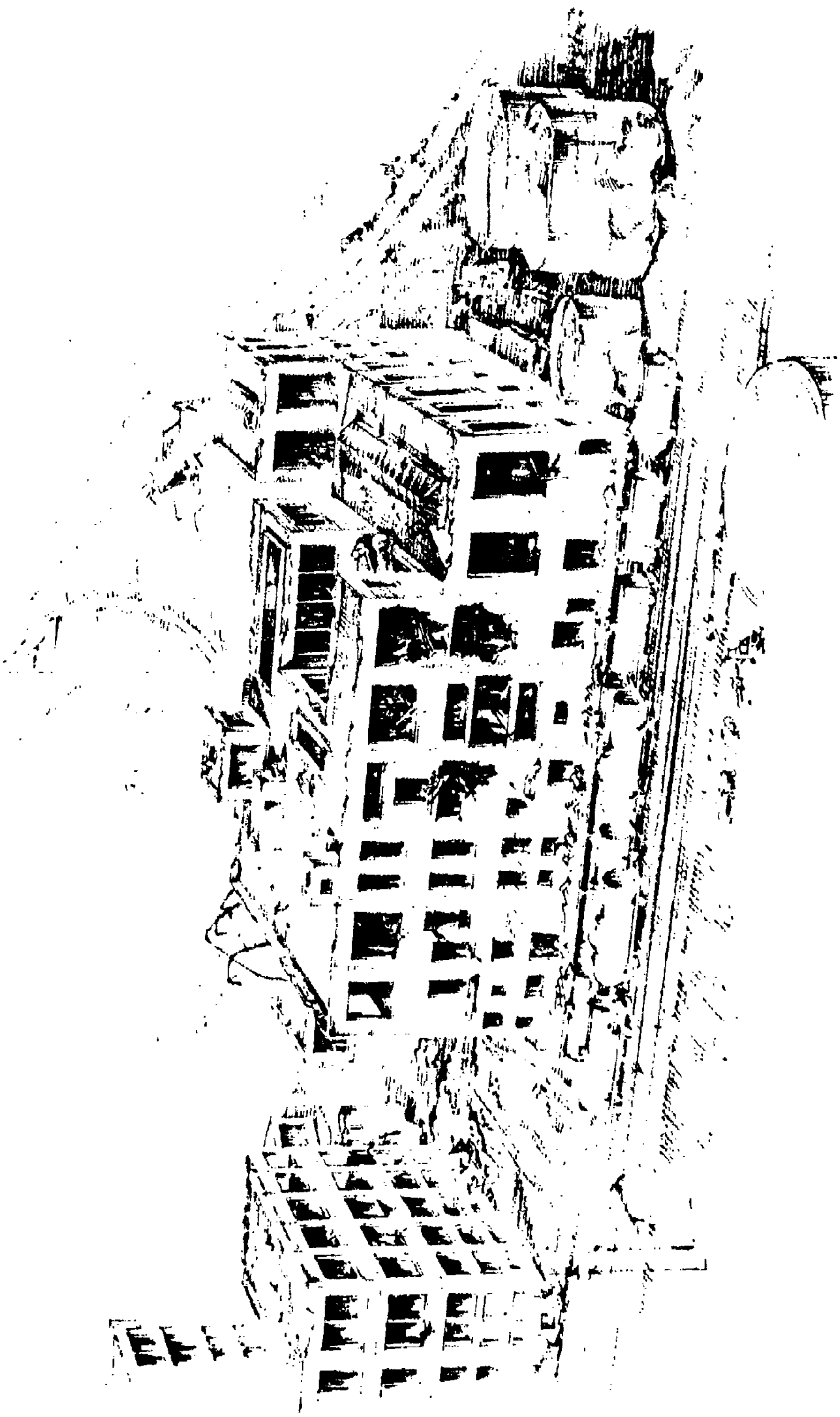
As overpressure approaches 2.5 psi, the upper portion of the brick wall of the boilerhouse will fail, thereby increasing the missile damage from flying bricks. Gauges, meters, recorders and controls will be damaged beyond repair. Piping and electrical wiring will also be damaged. At 2.5 psi, the bents of the structure which support the steam line between the boilerhouse, engine room and yeast house show deformation which increases until the bents collapse at a pressure of 4.0 psi. Without support, the steam lines will break.

At 3.0 psi, the stack will start to crack, a condition which worsens as pressure increases until the stack collapses at an overpressure of 5.5 psi. The molasses storage tanks when full show signs of cracking at 3.5 psi, thus allowing the contents to flow out and create a very messy and extensive cleanup problem.

3.3.3 High pressure blast range (5.5 psi to 14.0 psi)

Over this range, major structural failures and extensive damage to equipment occur, as illustrated in figure 3-4. At 5.5 psi electric power lines fail and the stack collapses. Depending upon the direction of the blast, further damage to buildings and equipment could result from this collapse. At a pressure of 6.5 psi or greater, the water tower will collapse and could incur further damage by falling upon other structures or equipment, depending on the direction of the blast.

The collapse of the water tower does not preclude the availability of water, because there are 12 deep wells on the property. These wells have electric motor-driven pumps which are manually started and stopped. When electric power is available, a large quantity of water, 1,000 gallons per minute, can be obtained. There are also connections with the city water system.



Damage to Yeast Factory at 7 psi Overpressure

Figure 3-4

As the pressure approaches 8.0 psi, the boilerhouse frame will fail and collapse on the equipment inside. At pressures greater than 8.0 psi, the damage to the boilerhouse equipment may be so extensive as to necessitate the erection of an entirely new boiler plant.

The destruction of the boilerhouse will result in the loss of the 1,500 KW of electricity required for the operation of the plant, since steam is used to run the generator and turbine in the engine room, and the available outside source of power, approximately 1,100 KW, is insufficient. The plant, therefore, could not operate in any processing capacity until the boilers and associated equipment were repaired or rebuilt, or a larger transformer is installed to bring the outside source up to the power requirements of the plant.

At or near 10.0 psi, the same conditions as those at the boilerhouse would exist at the engineroom after the collapse of the building on the equipment inside. Compressors for refrigeration and air pumps for the fermenter tanks will be damaged, but some of these units could be placed in service again with cannibalization. The compressors and equipment needed for refrigeration would be urgently needed to save the yeast in cold storage and should be repaired and in operation as soon as possible.

The yeast house will be severely damaged at a pressure close to 14.0 psi. The severe deformation of the structure could damage and perhaps ruin much of the processing equipment.

3.3.4 Thermal radiation

The hazard from thermal radiation is minimal, except, of course, to exposed personnel. The yeast plant is extremely clean, with no combustible trash either outside or inside. The plant is constructed of brick, which faces the interior as well as the exterior surface; hence, even mild charring is improbable. All equipment is housed within the building, most of it well away from windows. The one combustible item is coal, which is piled outside the building and could, under certain circumstances, be ignited. However, the coal pile is 200 or 300 feet from the building, and if ignited, would smolder slowly until such time as it was wetted down with water and the fires extinguished. The greatest danger would be the creation of missiles by the blast striking the coal pile.

3.3.5 Fallout

Radioactive fallout could be a hazard to personnel and could contaminate the material in process, particularly in the fermenter tanks. The large volume of air required for the fermenting process is brought in from the outside and could contain fallout dust, which would collect and settle in the tanks. Unless the fallout were very light, it would be impractical to filter satisfactorily such a large volume of air. Therefore, it could be advantageous to stop the supply of outside air during the fallout arrival period.

3.3.6 Shutdown

A shutdown of the plant could be done rapidly. Personnel could turn off switches, motors and valves and leave the plant without incurring subsequent damage to the equipment. If shutdown did not last longer than a few hours, the normal plant procedures for removing spoiled material, washing and sterilizing could be used.

Beyond this time, spoilage would increase to a point where the entire processing system would require cleaning and sterilizing before new ingredients could be introduced. It would then take approximately four days for these new ingredients to be carried through the various processing stages to packaging and shipping of the final product.

In general, no serious damage will directly result from a fast shutdown. However, to prevent blast damage to empty molasses storage tanks, such tanks should be filled with molasses or water if conditions permit, at the time of an attack warning to assure survival at a higher level of blast energy.

Gate valves in the well water pipes and in the connections with the city water supply should be closed to prevent loss of water from breakage of pipes within the building. Besides damaging the building, excessive water loss could hamper fire fighting.

3.3.7 Bottlenecks and weak links

The loss of steam which is essential to the process system would be a weak link at any overpressure greater than 0.5 psi.

Fallout could be a hazard to the process as well as the personnel. Because of the large volume of air required to assist in the growth of yeast, fallout could be drawn in with the air and could settle in the yeast as the air bubbles up through it. The point is somewhat academic, however, since if there were enough fallout to imperil the product, it should follow that the plant would be shut down with operating personnel in shelters or elsewhere.

3.4 RECOVERY

3.4.1 Summary of damage

Summaries of damage to structures and processing equipment are shown in tables 3-1 and 3-2 which follow.

In order to relate damage to processing equipment with the structural damage in table 3-2, a brief description of the structural damage is given.

3.4.2 Spare parts and cannibalization

The plant is well supplied with spare parts to take care of normal wear on all processing machines and on the specialized packaging equipment, but under extreme damage conditions additional parts and equipment would have to be obtained from the particular manufacturers.

Under emergency conditions, cannibalization would be necessary and could be carried out in the plant or through the exchange of cannibalized equipment with other plants.

3.4.3 Initiating emergency operation

Following a period of appraisal of damage, a decision will have to be made as to whether work required to bring about complete restoration should be performed, or whether the plant should be operated under emergency conditions by performing the minimum amount of repair consistent with the quantity and quality of production levels desired.

The minimum requirements to resume operations under emergency conditions for each of the three blast damage ranges are as follows:

Operation following low blast damage (0.0 psi to 2.5 psi)

The plant could operate without any repair work. Before operations are started, the equipment will have to be checked and cleaned. All glass, dust and debris must be removed from open tanks, vats, processing equipment, and packaging units to prevent contamination of the product.

After a final check of all equipment, the plant could go into production with repair of windows postponed. The molasses storage tanks could be repaired later, as their failure is not critical under emergency production conditions. Railroad tank cars which transport molasses to the plant could be used as storage facilities until the tanks are repaired. Since the underground pipes run from the railroad siding to both the storage tanks and directly into the zulauf tanks in the building, bypassing the broken storage tanks will not be a problem.

Operation following medium blast damage (2.5 psi to 5.5 psi)

Debris from the failure of the brick wall at the boilerhouse must be removed before equipment can be inspected, cleaned and repaired. The wall does not require rebuilding for emergency operation of the boilerhouse. The steam

Table 3-1 Summary of Damage to Structures

Pressure Psi	Boiler-house	Molasses Storage Tanks	Stack	Steam Line Trestle	Water Tower	Engine-room	Yeast-house
0.1	Glass cracking					Glass cracking	Glass cracking
0.5	All windows Siding Fail					windows fail	windows fail
1.0		(Empty) Distort and cracking					
2.0							
2.5	Solid brick wall Fails						
3.0			Concrete Cracking				
3.5		(Full) cracks at joints (side & bottom)					
4.0				Overturns			
5.0							
5.5			Collapse				
6.0							
6.5					Full Collapse		
8.0	Frame Failure						
10.0						Frame Failure	
14.0							Severe Damage to Frame

Table 3-2 Summary of Damage to Processing Equipment

Structural	Critical Overpressure	Processing Equipment
Missile damage in boilerhouse	0.5	Damage to equip. such as gauges & instruments.
Molasses tank (empty) frame distortion	1.0	Tank shows cracks.
Wall fails in boilerhouse	2.5	Damage to gauges, control panel, meters, and pump accessories.
	3.5	Severe cracking of molasses tank.
Steam line bents overturn	4.0	Steam line severely damaged. Steam lost.
Stack collapses	5.5	Connections to boilerhouse damaged severely.
Water tower collapse	6.5	Tank and piping damaged.
Boilerhouse frame fails	8.0	Boilers, cook bunkers, furnace burners and pumps damaged. Control panels, gauges and meters demolished.
Engineroom frame failure	10.0	Motors damaged. Control panels & gauges demolished.
Yeasthouse frame deforms	14.0	All processing equipment damaged

line and a supporting system, whether similar to the original structure or temporary, would be required for the delivery of steam to the engineroom and yeast house.

Operation following high blast damage (5.5 psi to 14.0 psi)

In this range, the minimum repair requirements will include those listed above for the low and medium ranges, as well as the following. After collapse of the boilerhouse at 8.0 psi, the rubble should be removed and the equipment checked, cleaned and repaired or replaced. The same procedure will be necessary after the failure of the engineroom at 10.0 psi. In both instances, the structures need not be erected until later. The stack need not be rebuilt immediately, since it uses forced draft fans, provided that the wind is not blowing toward the air pumps which bring air into the fermentation process.

These conditions are far from ideal even for emergency operation, but the plant would be in operation with 8,500 man-days of work.

3.4.4 Shortcuts

Because the manufacture of yeast is essentially a very simple operation, albeit conducted on a large scale, there are no shortcuts possible of the kind available to more complex operations; for example, production of whole wheat in flour milling. There are, of course, excellent opportunities for cannibalization, since the eight fermenter tanks operate identically, hence have interchangeable parts. However, no stage of the operation can be omitted; the ingredients of yeast, air, water, and molasses are all essential and the omission of any one of them obviously breaks down the entire manufacturing process.

Because of the simplicity of the operation, yeast can be cultivated in the home. This was common practice at the turn of the century. The housewife "fed" her yeast culture on such common household items as sugar, molasses, potato peelings and raisins. If for any reason the yeast culture died, she simply borrowed yeast from a neighbor and started the process over again.

It is virtually inconceivable that there could be a shortage of yeast for these processes, due to the thousands of bakeries which have their own supply of yeast on hand. In the event that their supplies were cut off, the bakeries could cultivate their own batches of yeast in much the same manner as the housewife.

3.4.5 Utilities

Steam supply

The supply of steam is essential to the processing of yeast and is vulnerable at the low overpressure of 0.5 psi, when loss of steam will be incurred by missile damage to gauges and light instrument steam lines. The boilers must be repaired as soon as possible, in order to start up production.

Water supply

The underground water mains are not considered vulnerable; however, any damage to water lines within the plant buildings would result in a great loss of water needed for firefighting and boiler feed. If possible, gate valves at the wells and connections to the city water mains should be closed prior to attack to prevent this loss of water.

Electric supply

Electricity is essential in the operation of the plant, particularly in the supplying of water from wells and the supplying of air to the fermenting tanks. The 1,500 KW required for operation is supplied in part by one or both generators in the engineroom. The generators are run by an outmoded turbine. The panel board containing the switch gear is 50 feet long, 6 feet high, and is also very old equipment by today's standards.

The balance of the electrical power, not generated by plant equipment, is supplied by an outside electrical company. There are three 200 KVA transformers on the plant property, owned by the electrical company. The electrical power supplied by these transformers is 1,100 KW, which is insufficient to supply the needs of the plant if the generators are damaged to the point where repair requires a considerable amount of time.

To initiate emergency startup after serious damage to the generators or steam supply, it would be more economical and far more expedient to increase the capacity of this outside electrical supply.

3.4.6 Repair required to resume normal operation

Low blast pressure range

In general, the damage over this range will be minimal but a considerable amount of work will be required to clean up dust, dirt and debris, with some minor repairs necessary to bring the plant up to preattack operating conditions. All exposed interiors of tanks, vats and other processing equipment will require thorough cleansing; glass gauges, meters and control panels will need replacing or repairing; and storage tanks should be checked for cracks and repaired.

The major items to be checked and repaired are those associated with the boilers' steam supply.

The plant could be in operation in approximately ten days, with a total of 1500 man-days to complete repair. The replacement of windows and repair of siding could be accomplished after the plant is in operation.

Medium blast pressure range

Over this range, a considerable amount of damage will be experienced. However, it is reparable and recovery can be made in a matter of 30 days.

Of particular concern is the loss of the steam lines from the failure of the frame bents which must be rebuilt.

At the boilerhouse, the upper portion of the brick walls will require rebuilding, gauges, meters, recorders and controls will have to be replaced and piping and electrical wiring repaired.

The molasses tanks will require checking, cleaning and the welding of any cracks in the tank walls. Full tanks would require emptying prior to cleaning and repairing.

Throughout this range, the work required to put the stack in proper operating condition will be the repointing of the brick.

High blast pressure range

Over this range, major structural failures and extensive damage to equipment occur, requiring considerable time and personnel for complete recovery.

The collapse of the stack creates rubble which would have to be cleared away before the work of rebuilding the stack, and its connection to the boilerhouse, could be started.

After the collapse of the water tower it may be possible to salvage portions of the tower; if not, a completely new tower will have to be built.

The boilerhouse frame failure at 8.0 psi will require rebuilding of the entire structure and the cleaning, overhauling and repairing of all the equipment. The boilers would require close inspection and a decision would have to be made as to whether they could be economically repaired or require complete replacement. All instruments, recorders and controls will demand replacing and the furnaces may need rebuilding. At pressures greater than 10.0 psi, the damage to the boilerhouse may be so extensive as to necessitate the erection of an entirely new boiler plant.

The destruction of the boilerhouse will result in the loss of the 1,500 KW of electricity required for the operation of the plant since steam is used to run the generator and turbine in the engineroom, and the available outside source of power, approximately 1,100 KW, is insufficient. The plant, therefore, could not operate in any processing capacity until the boilers and associated equipment are repaired or rebuilt, or a larger transformer is installed to bring the outside source up to the power requirements of the plant.

3.4.7 Substitutes

The main input material for yeast production in this country is molasses, but other materials have been used from time to time, such as potatoes and various grains. In Germany, wood has been used quite successfully, and this has become an increasingly important source.

Items that can be used in place of yeast for baking include such materials as baking powder, baking soda, and eggs. These are all well-known leavening agents and can be used for various types of baking.

Yeast has been and can be grown in the home, and a constant supply can be maintained rather easily. This may be an important point to consider during times of international crises, as a postattack proliferation of yeast in homes could play a vital role in home baking, thus greatly affecting the postattack diet.

3.4.8 Increased production capability

This plant works on a continuous three shift basis. The limiting factor is the growth of yeast in the fermenter tanks and the plant is usually producing at full capacity. The remainder of the process, the pressing and packaging, is usually operated on a one-shift basis, but three shifts could be initiated to handle more production provided more fermenter tanks were installed to grow the yeast.

With the frame failure at the engineroom, compressors for refrigeration and air pumps for the fermenter tanks would require repair, although it is possible that some of these units could be placed into service again with cannibalization. The compressors and equipment needed for refrigeration would be urgently needed to save the yeast in cold storage and should be repaired and in operation as soon as possible.

Much of the processing equipment at the yeasthouse might require considerable repair or replacement, due to severe deformation of the building frame. At this point, an investigation and study of the damage and repair cost will be necessary to determine whether the plant and its facilities can be repaired economically or whether the rubble should be cleared away and a new plant built.

3.4.9 Estimated man-days required for repair for each level of blast overpressure

These estimates are tabulated on the following charts and figure 3-5 which graphically presents the repair effort in man-days to initiate emergency operation and to resume normal operation.

YEAST PLANT

Low Blast Damage Range 0.0 to 2.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
0.1	all glass cracks dust, dirt, debris	clean	labor	10	10	100
0.5	complete window failure	replace windows	labor	10	10	100
	metal siding on boilerhouse fails	remove loose siding and replace	labor	30	10	300
1.0	molasses storage tanks (empty) exhibit cracking	check for damage -- straighten -- weld	labor ironworkers	30	10	300
			Structural			800
	PROCESS					
0.1	dust & fallout	check for contamination --	chem. eng. labor	10	10	100
0.5	dust, glass and siding-missile damage to equip. in boilerhouse	clean overhaul and repair equip.	dept. heads tradesmen labor	30	10	300
1.0	molasses tanks crack (empty)	check equip. clean	labor	30	10	300
			Process			700
			Structural			800
		Total Man-Days for Low Range				1,500

YEAST PLANT

Low Blast Damage Range 0.0 to 2.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
	clean up dust & glass shards			10	10	100
	Process					
	check for contamination & clean			10	10	100
	check & repair boilerhouse equipment			10	10	100
		Total Man-Days for Low Range				300

YEAST PLANT

Medium Blast Damage Range 2.5 to 5.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
2.5	upper portion of solid brick wall of boilerhouse fails	clean up debris dust and dirt rebuild wall	labor engineer tradesmen	50	30	1500
3.0	stack -- concrete cracking	check and repair	engineer tradesmen	20	30	600
3.5	molasses storage tanks cracking at joints, sides and bottom	remove molasses, weld cracks and repair deformed plates	labor tradesmen	20	30	600
4.0	steam line bents overturn	rebuild bents	labor tradesmen	10	30	300
			Structural			3000
	PROCESS					
2.5	boilerhouse wall failure	check boilers, pumps, feeders meters, gages controls	labor engineers tradesmen	20	30	600
3.0	concrete stack cracking	check connections to boilerhouse	labor	4	30	120
3.5	molasses tanks cracking (full)	molasses storage operation during tank repairs	dept. heads labor	10	30	300
4.0	steam line bents overturn	replace steam line	engineer tradesmen labor	10	30	300
			Process			1320
			Structural			3000
		Total for 2.5 to 5.5 psi				4320
		Total for Low Range				1500
		Total Man-Days for Medium Range				5820

YEAST PLANT

Medium Blast Damage Range 2.5 to 5.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
2.5	clean up debris at boilerhouse			4	25	100
4.0	rebuild temporary bents to support steam lines			12	25	300
	Process					
2.5	clean, repair & replace boilerhouse equipment			12	25	300
4.0	replace steam line			12	25	300
		Total for 2.5 to 5.5 psi				1000
		Total for Low Range				300
		Total Man-Days for Medium Range				1300

YEAST PLANT

High Blast Damage Range 5.5 to 10.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
5.5	stack collapses	rebuild	engineers tradesmen labor	10	100	1000
6.5	water tower (full) collapses	rebuild	tradesmen labor	15	100	1500
8.0	boilerhouse frame fails	rebuild	tradesmen labor	40	100	4000
10.0	engine room frame fails	rebuild	tradesmen labor	20	100	2000
			Structural			8,500
	Note: At 14.0 psi or above it is uneconomical to repair the plant					
14.0	severe frame damage at yeast house	rebuild				
	PROCESS					
5.5	stack collapses	rebuild connections to boilerhouse	tradesmen labor	5	60	300
6.5	water tower (full) collapses	repair piping & connections	tradesmen labor	5	60	300
8.0	boilerhouse frame fails	check & repair boilers & related equip.	engineer tradesmen labor	50	60	3000
10.0	engine room frame failure	overhaul and repair all equipment and controls	engineer tradesmen labor	50	60	3000
			Process			6,600
			Structural			8,500
		Total for 5.5 to 10.0 psi				15,100
		Total for Medium Range				5,820
		Total Man-Days for High Range				20,920
14.0	severe frame damage at yeast house					

YEAST PLANT

High Blast Damage Range 5.5 to 10.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
5.5	install steel stack			10	50	500
8.0	clean up debris at boilerhouse			4	50	200
10.0	clean up debris at engine room			4	50	200
	Process					
5.5	repair stack connections to boilerhouse			6	50	300
8.0	repair boilerhouse equipment			60	50	3000
10.0	repair engine room equipment			60	50	3000
		Total for 5.5 psi to 10.0 psi				7,200
		Total for Medium Range				1,300
		Total Man-Days for High Range				8,500

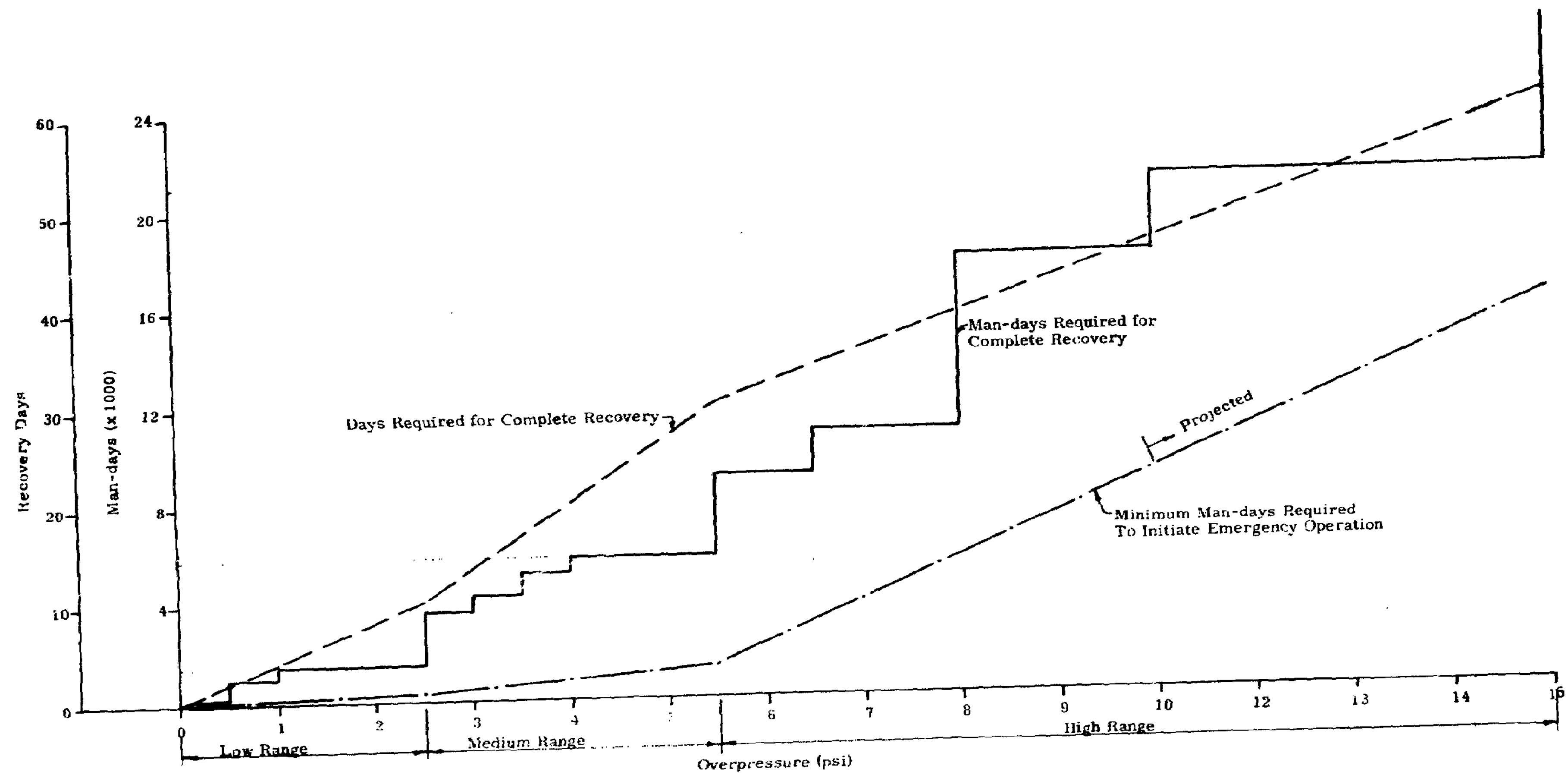


Figure 3-5 Recovery Chart - Yeast Processing Plant

3.5 CONCLUSIONS

Yeast is a critical item in the baking industry, particularly in baking bread. There are, however, substitutes such as baking soda, baking powder, and beaten eggs which cause dough to rise and which work reasonably well, particularly in non-bread items such as cakes, cookies, and pie crusts. And unleavened bread, while of unusual flavor and consistency, is nourishing and could be made without yeast in homes or in bakeries.

Yeast can be raised in the home and in bakeries as well. However, the latter would find it difficult to grow all the yeast required without some supplementation from the outside, as from surviving yeast plants.

The industry is extremely vulnerable, because the 16 compressed yeast plants are located in major metropolitan centers. Their output could be supplemented by brewer's yeast, but most of these plants, too, are in the same areas.

4. SUGAR INDUSTRY

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4. SUGAR INDUSTRY

4.1 A REVIEW OF THE SUGAR INDUSTRY

4.1.1 General

The three leading United States food imports are coffee, sugar, and meat products.[2] Imported meat is significant in terms of dollar volume but under most foreseeable conditions, its loss could be replaced by increased domestic production. Because the beverage has become a national habit, coffee could be important as a morale factor, but has little nutritional significance. Since it is brought in by ships, the postattack loss of much, or most, of our imported sugar through loss of harbor facilities should be taken into account and could be a worthwhile subject for further study in depth. There appear to be no data, for example concerning the extent to which beet sugar production could be increased under emergency conditions and the time required to effect the increase. There does seem to be considerable potential. The American Beet Sugar Association has estimated that the 1965 beet sugar production, if free of Government restrictions, "could easily exceed 3,500,000 tons by 1965" under normal market conditions.[22] (The 1965 quota is 2,650,000 tons).

It should be emphasized that the sugar industry is doubly vulnerable: first, because the majority of its raw material is imported, and secondly, because of the limited number of sugar processors in this country. The 22 operating refineries in the continental United States process approximately 70% of all the sugar consumed in this country.

Sugar is the biggest exception to the general rule that the United States is self-sufficient in food. Because the majority of the raw sugar processed in this country is of the imported cane variety, as opposed to domestic beet, the Revere cane refinery was selected for analysis. The Revere Sugar Refinery (a subsidiary of United Fruit Company) processes approximately 500 million pounds of sugar per year or 2.7% of the total national production.

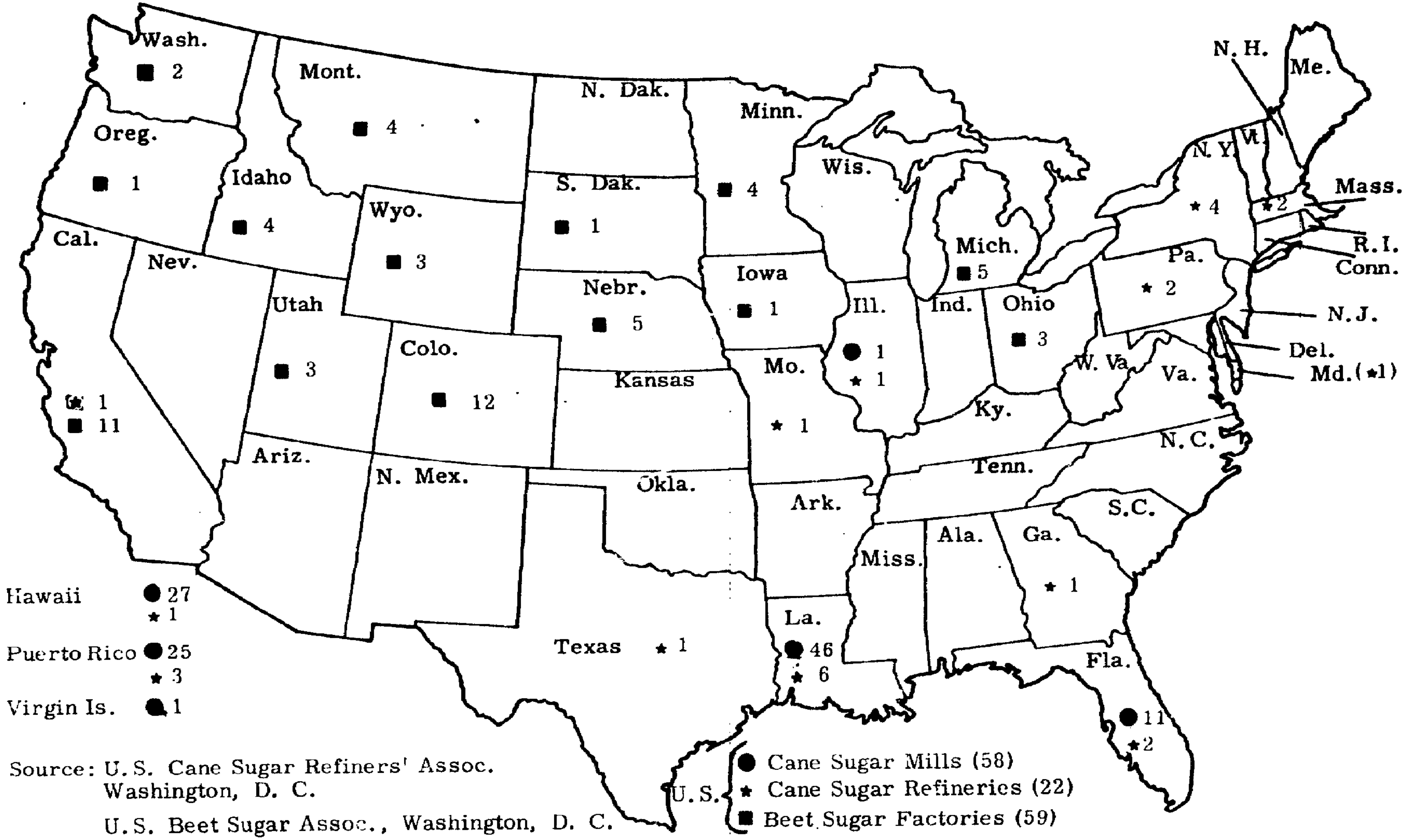
Sugar and syrups provide a substantial portion of the nation's total food energy. The 18 billion pounds of sugar consumed in 1961 amounted to about 100 pounds per person and 15.9 % of all food energy (calories).[23]

4.1.2 Geographical locations of refineries, factories, and mills

The 136 mainland sugar processors are shown, broken down by states and possessions, in figure 4-1. There are three different types of processors; descriptions of them and their functions follow.

Sugar refineries

The 22 mainland sugar refineries process only raw cane sugar, most of which is received from off-shore possessions or foreign countries. Only 9.7% of the



Source: U.S. Cane Sugar Refiners' Assoc. Washington, D. C.

U.S. Beet Sugar Assoc., Washington, D. C.

Figure 4-1 Plants Producing Raw and Refined Sugar from Sugar Cane and Beets, by states, 1963 raw sugar comes from mainland cane (see 4.1.4). Five of the refineries have their own mills, and thus function as integrated operations, similar to those of the beet sugar industry. Most refineries are located on large bodies of water, to facilitate unloading of the raw sugar from ships. This raises the question of possible vulnerability as a result of tsunami action, as well as blast damage to port equipment.

Beet sugar factories

The 59 beet sugar factories are integrated operations in that they receive the whole beets, slice them, reduce them to raw sugar, and then refine the raw sugar into the finished product. Under emergency conditions, the beet factories could process the raw cane sugar which is normally sent to the refineries. But the refineries cannot process beets, nor can the beet factories produce raw sugar from sugar cane. The latter is the function of the sugar mills.

Sugar mills

The 58 mainland sugar mills process sugar cane into raw sugar, which in most cases is then shipped to refineries. As previously noted, the exceptions are the five refineries which also conduct their own milling operations.

4.1.3 Beet sugar industry

This report is primarily concerned with repair analysis of a cane sugar refinery. However, the beet sugar industry in the United States is probably less vulnerable than the cane sugar industry, because there are more beet factories (59) than cane refineries (22), and beets are not imported. It is quite possible that an attack pattern could involve destruction of the nation's major port facilities and this, in turn, would preclude the unloading of raw cane sugar from ships.

Beet sugar currently accounts for 30% of all sugar consumed in this country, an increase from the 25% level in 1962, and the 20% average level of the early and mid 1950's. There are two reasons for this growth: first, the sharp acreage reductions on other (surplus) crops and low prices for other crops; and second, the halt in importation of Cuban sugar.[15]

This increased production has not been accompanied by an increase in factories. On the contrary, while three new factories have been built since 1950, 24 have been torn down or idled. The remaining plants are far more efficient, as witnessed by the fact that average annual production per factory in the 1950's was 30,000 tons, compared to 50,000 tons today.[15] The declining number, however, is an obvious postattack liability.

4.1.4 Sources of sugar supply

The various amounts of sugar, from the many sources, are fixed yearly by the Secretary of Agriculture, in order to stabilize prices and assure consumers of an adequate supply. The largest single source is domestic beet, with a quota of 2.65 million tons. The total 1965 quota of 9.2 million tons breaks down as follows:[24]

Mainland beet	2.65 million
Puerto Rico	1.40 million
Hawaii	1.12 million
Phillipines	1.05 million
Mainland cane	895.000
Mexico	358,617
Dominican Republic	357,566
Peru	222.691
Brazil	204.057
Australia	171,923
British West Indies	1[illegible]2,690
South Africa	98,047
India	89,224
Taiwan	63.026
Argentina	59,244
Ecuador	45,652
Fiji Islands	41,954
French West Indies	39,706
Nicaragua	37,395
Guatemala	36,826
Costa Rica	32,143
Haiti	29,168
Colombia	27,038
El Salvador	15,820
Virgin Islands	15,232
Mauritius	13,866
Panama	13,298
Rhodesia	8,403
Ireland	7,983
Malagasy	6,723
France	5,315
British Honduras	3,845
Venezuela	2,458
Reunion	2,038
Belgium	1,744
Turkey	1,408
Reserve for later allocation	233,429

4.1.5 Transportation

At the Revere Sugar refinery and most others, shipments of raw sugar are received by ship, at the rate of approximately one or two per week. The raw sugar warehouse is on the pier and unloading is direct and convenient.

The finished product is shipped out by rail and by truck, and at Revere the facilities for both are at hand and well arranged. Shipments of granular sugar are made in bulk, as well as in bag and carton forms, and a high grade syrup for bakeries which is handled in 50-gallon steel drums.

Mention was made in preceeding sections (4.1.1 and 4.1.3) of possible postattack disadvantages in regard to imported cane sugar. While the roles of transportation in general, and of shipping in particular, are not within the scope of this repair analysis, the fact that the country depends on shipping for the supplying of 60% of all its sugar, points out the essentiality of marine transportation, even before the manifold problems of domestic rail and truck transportation of sugar are considered.

4.1.6 Trends

Recently there has been a change in demand at many bakeries from granular sugar to a high quality sugar syrup. A considerable saving is found in using syrup supplied in barrels. This can be used directly and immediately as compared to the older method of dumping bags of sugar into large vats and melting it down to syrup form.

From the postattack point of view, the most significant trend is no doubt the recent increase in domestic beet sugar production although, as noted earlier, this advantage is somewhat offset in the declining number of factories.

4.1.7 Assumptions

All blast calculations have been made on the basis of a blast center located on land. If the blast should be located in the water, in or near Boston harbor, a tsunami could cause additional wave and flood damage; these conditions are not discussed here.

No estimates are given in this report concerning the possible size and consequences of a postattack shortage of raw sugar. Shipping may be delayed or lost, and sugar production could be delayed or closed down, due to lack of raw material.

4.2 SUGAR REFINERY

4.2.1 General Description

The Revere Sugar Refinery (see figure 4-2) was built in Boston in 1918 and has had only minor alterations since. As noted earlier it processes only raw, cane sugar. The production facilities are housed in a complex of about 10 buildings, among which are a raw sugar warehouse, melthouse, filterhouse, panhouse, refined sugar warehouse, and a refined sugar storage bin house atop the latter. Adjacent to the production plant are the main office and laboratory building, the boilerhouse, turbinehouse, machine shop, pumphouse, and a few minor outbuildings.

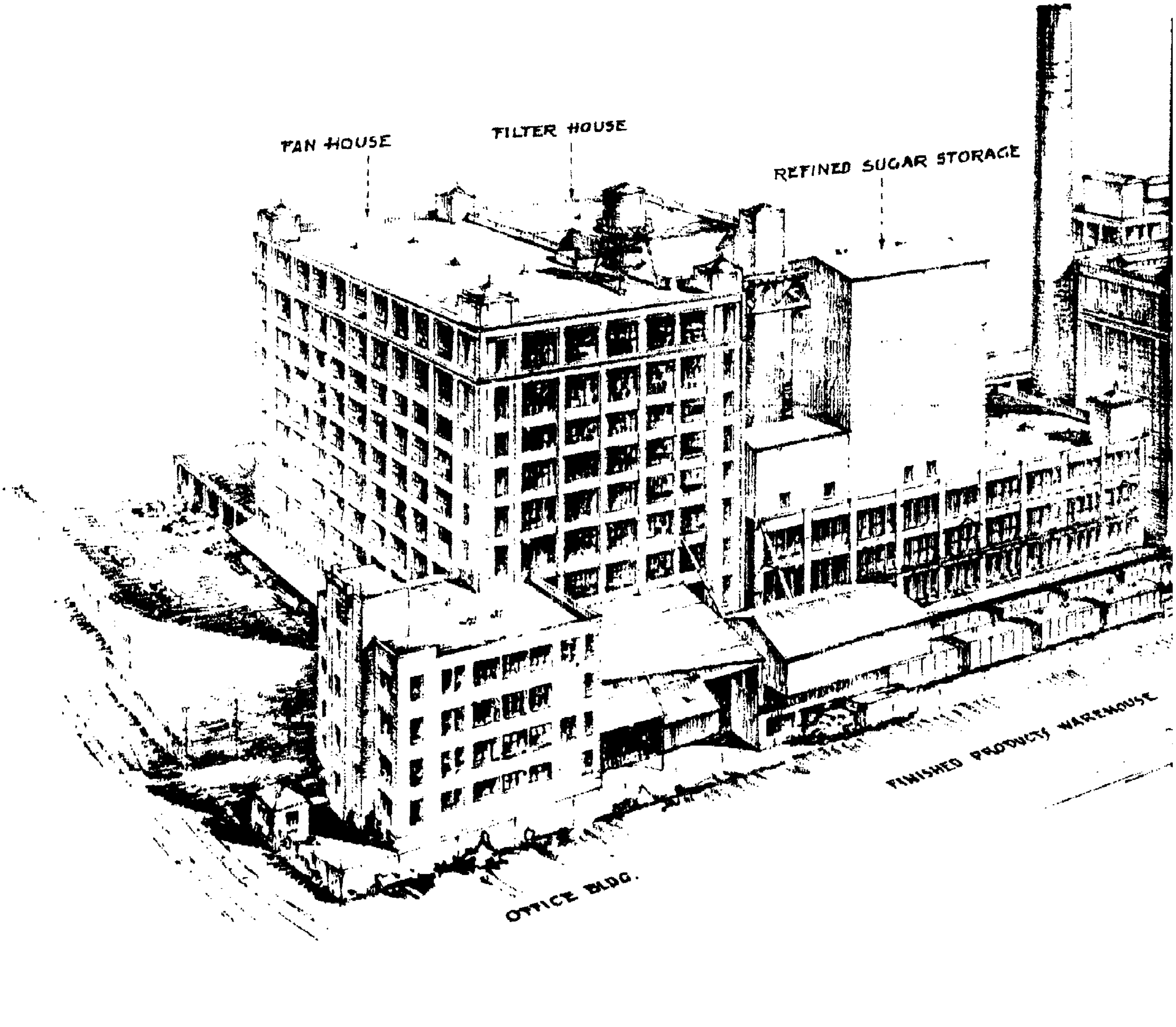
The melthouse, filterhouse, and panhouses have steel frames encased in concrete, concrete floors and roof, and brick curtain walls of approximately 60 percent fenestration. Lateral resistance is furnished by the masonry walls. The structural condition, in general, is very good.

The two brick boilerhouse stacks have experienced mortar joint failures near the openings, with the result that 5 feet of one and 10 feet of the other have been removed, and hoop reinforcements put in place. Originally, the boilers were coal fed and a stack height of 190 feet was needed to provide draft. The boilers are now oil fired; this, plus a later change to forced draft, has lessened the essentiality of the stacks. In an emergency, operations could proceed without full draft height. All of the plant's power requirements are met by steam from this boilerhouse, including extensive electrical needs. The need for steam was an important reason for the original establishment of an independent power facility.

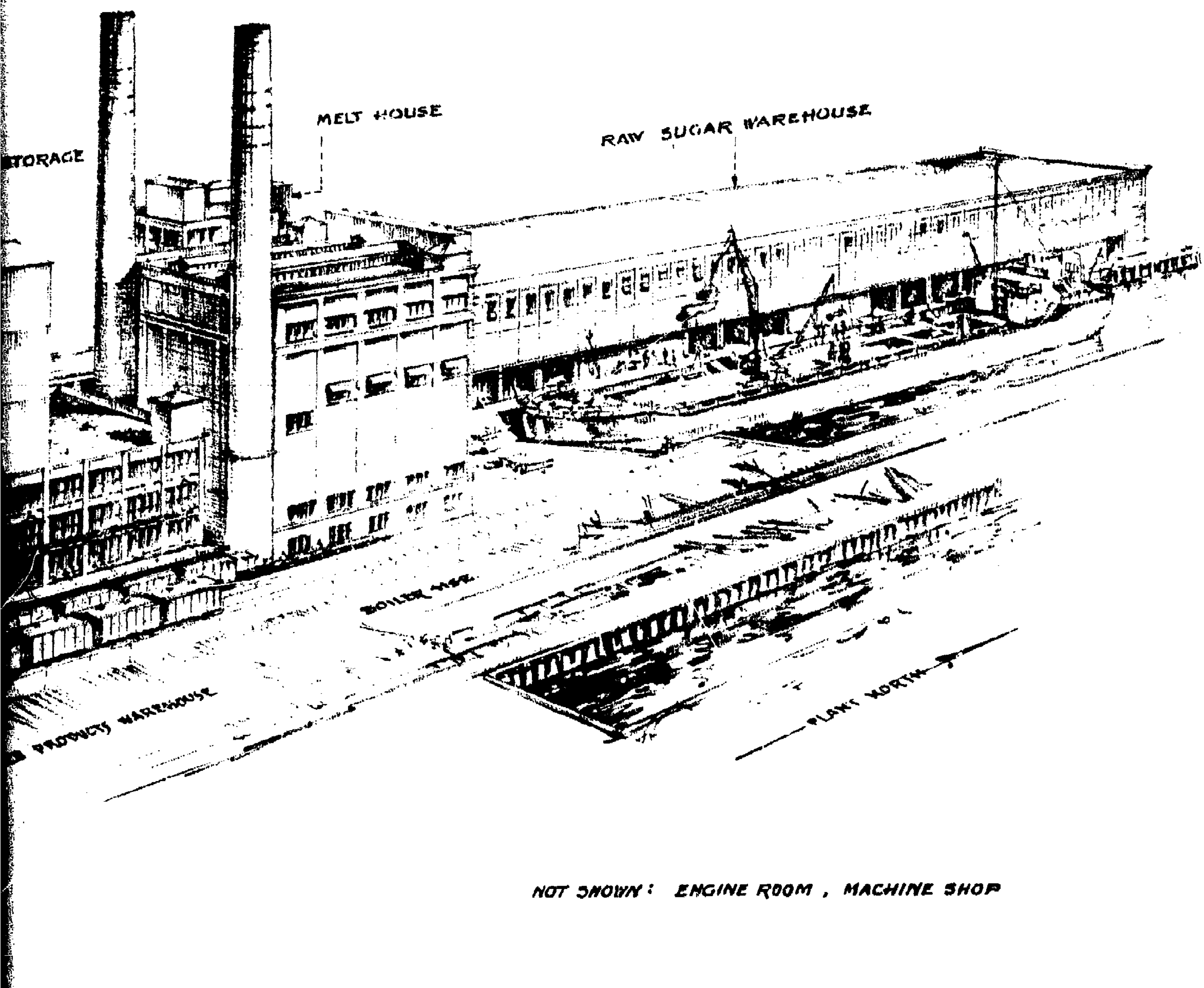
Several years ago, a fire broke out on the wharf and burned a portion of the raw sugar storage warehouse, but in rebuilding the original design was followed. The heat intensity of the fire was sufficient to cause twisting and failure in the light steel frame of the northerly portion of the building, but production was not seriously interrupted. This building, essentially a light steel frame which supports six cranes and a conveyor, is one of two buildings in the complex most vulnerable to nuclear attack. The other one is the finished sugar bin building, atop the packing building and built only a few years ago. It houses six refined sugar storage bins (each 17 feet in diameter by 50 feet high) and an automated, completely enclosed, loading-out system of conveyors and screens in a light steel frame 80 feet high covered by aluminum sheet.

Raw material arrives in company ships which have special unloading rigging to conform with the dock equipment. One ship per week brings about 11 million pounds of sugar and the storage warehouse has a capacity of 50 million pounds. Time in storage does not appreciably affect the sugar.

About 25 percent of the product is shipped as syrup, which requires less processing than granulated sugar.


FAN HOUSE
FILTER HOUSE
REFINED SUGAR STORAGE
FINISHED PRODUCTS WAREHOUSE
OFFICE BLDG.

Sugar Ref



Sugar Refinery

Figure 4-2

Practically all of the equipment is very rugged. A continuous, gravity-process flow is employed which necessitates carrying the raw sugar to the top floor of the melthouse from whence the individual processes succeed each other as the sugar is carried through the plant by gravity. As the plant is presently constituted, the complete process requires that the sugar be lifted over 100 feet at least five times before the final processing cycle has been completed.

The Domino Sugar Company, adjacent to the Revere plant, has erected a modern sugar refinery which affords a sharp contrast to the almost five-decades-old refinery. For example, one striking difference is the manner of raw sugar storage. Domino employs a somewhat hemispherical thin-skinned dome about 70 feet in radius, which is fed from ship to storage by means of a mechanical conveyor which empties into the crown of the dome. Because the igloo-shaped structure roughly approximates the angle of repose of the raw sugar, presumably no secondary spreading equipment need be employed.

4.2.2 Operation

The refining process is separating the sucrose and impurities in raw sugar. A simplified diagram of this process is shown in figure 4-3.

Raw sugar warehouse

A vertical bucket elevator is used to lift the raw sugar from the hold of the ship and is raised and lowered by means of booms on board. Two elevator units are used, one for each of the two large rear holds. There is a clamshell bucket to unload the front hold. The sugar is fed onto a conveyor belt which delivers it into elevators in the storage building. These raise the sugar to hoppers and into a weigh scale where government inspectors check the material received, for both quality and weight. From here, it is distributed by conveyors and overhead clamshell buckets handled by crane operators

The storage building is 700 feet long, has three bays that run the full length with open, clear space for the cranes to handle the raw sugar. The sugar in storage does not change or deteriorate and may be kept safely for months without moving or processing. This permits very simple storage and handling facilities.

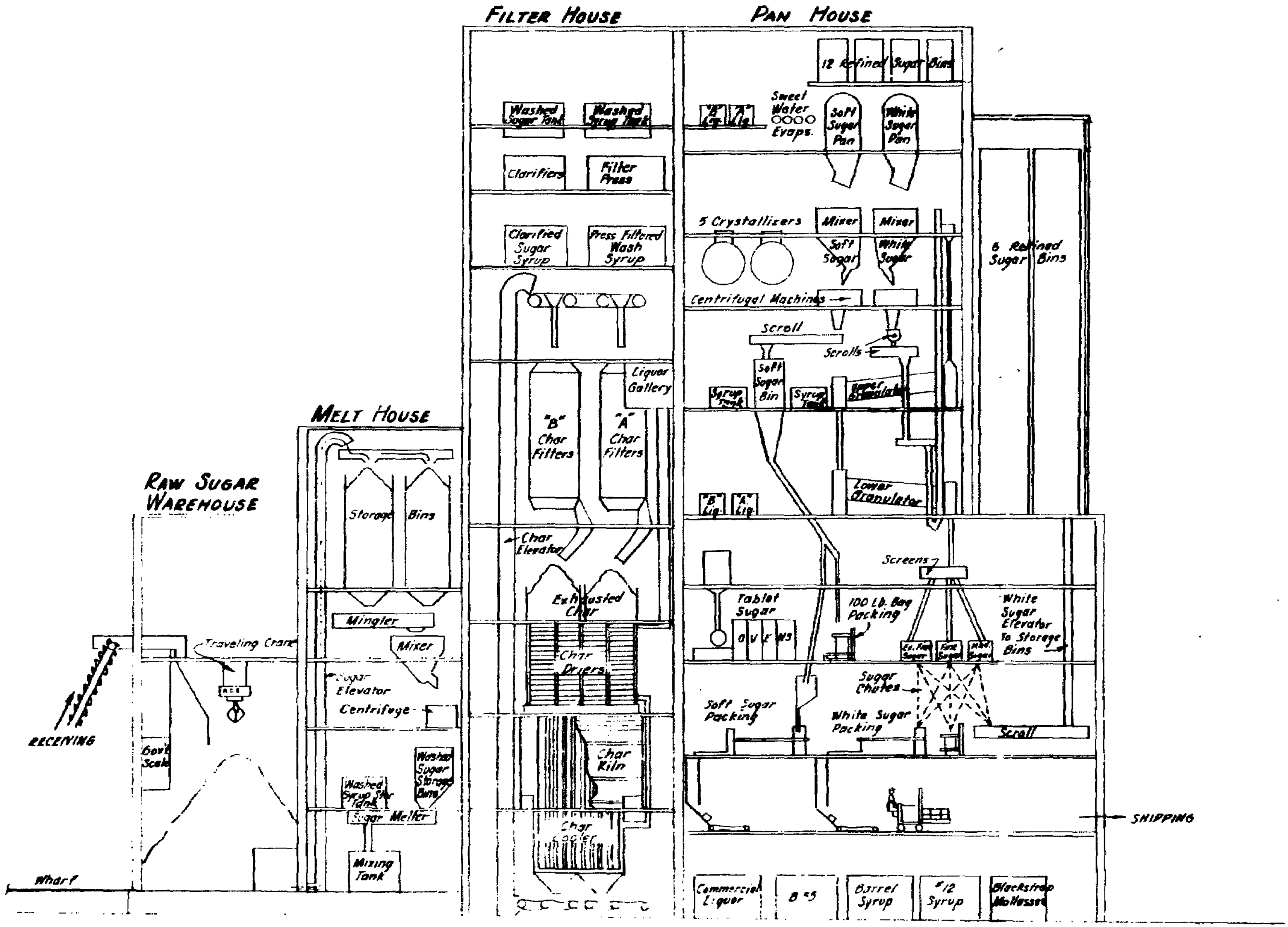


Figure 4-3 Simplified Diagram of Sugar Process

Melthouse

Raw sugar delivered from the warehouse is placed on belt conveyors at the top of the melthouse and is fed into two open storage bins at the top floor.

From the bottom of these bins, raw sugar is drawn off into a screw conveyor called a mingler, where syrups are added. The resultant mixture is then fed into a mixer. Here they are thoroughly mixed and kept ready for the centrifugal machine, where water, molasses, and most impurities are separated from the sugar and drained away into a tank on the floor below, while the washed sugar is discharged into another. All sugar and syrup is heated and melted, ready for the filterhouse.

Filterhouse

The melted centrifugally-washed raw sugar is treated with phosphoric acid and lime and passed through clarifiers where heat and aeration, plus the calcium phosphate floc formed, remove the foreign material from the melt liquor.

The clarified melt liquor is then passed through bone char. The bone char is in granular form and has the ability to remove impurities and color from the clarified sugar liquor. The char filters are tanks 20 feet high and 10 feet in diameter. The sugar or syrup is added to each tank in batches and allowed to drain through and out the bottom, as shown in figure 4-3 on the preceding page. The "A" char filters are for syrup and the "B" char filters are for sugars. These are kept separated as "A" liquor and "B" liquor, transferred to the panhouse and held in heated tanks. When the char in the filters has exhausted its ability to remove color and impurities from the sugar liquor it is washed free of sugar. The char is further washed to remove some of the material it has absorbed, then dried, and passed through kilns at high temperatures (usually 960^{O}F). The char is then cooled and sent back to the char filters for another sugar liquor cycle.

Panhouse

Char liquor is received in tanks on the fifth floor, where it is kept heated and ready. When required, it is pumped to raised tanks on the top (or ninth) floor, from which it goes into one of two types of evaporator tanks, called pans. One set is called soft sugar pans, and the other white sugar pans.

The pans are made of heavy plate material 12 feet in diameter and approximately 12 feet high, with a dome top and funnel bottom. Five thick glass windows are provided at various heights to observe granulation conditions.

The pans are heated under partial vacuum to facilitate the boiling of the sugar liquor and produce crystallization by removal of water from the liquor which becomes supersaturated. To develop the vacuum, vapor from the pans is passed through a heat exchanger cooled with a large volume of seawater pumped there solely for this purpose. Approximately one million cubic feet of seawater per week are used.

The boiling in vacuum starts at 135°F. When crystals start to form, the process is ready for complete crystallization. A quantity of powdered sugar is shot into the pan under vacuum to stimulate the formation of crystals, which takes place almost immediately. After the pan is full, the vacuum is broken and the pan emptied by gravity into a tank below. By now, the material is in a slushy condition, similar to wet snow, and is ready for centrifuges.

These centrifuges are identical to those in the melthouse and hold about 1200 pounds of material for each load. They are held in a vertical position and turn at approximately 1800 r.p.m. for only a few minutes, depending on the condition of the mixture. A quick wash of water is sprayed in for a final rinse-off before the centrifuge is stopped, and the sugar is unloaded. This is pure sugar, completely refined and ready to go directly into cubes or tablets or to be sent to the drying kilns before packaging as granular sugar.

The soft sugars, or brown sugars as they are commonly called, follow a parallel path through the panhouse using the syrup materials or "B" liquors as specified in this plant. As the soft sugars pass from the centrifuges they are ready for packaging on the second floor.

Drying kilns

The sugar as it leaves the centrifuge is conveyed to the drying kilns to remove any excess moisture that may still be attached to the outside surface of each grain, which if allowed to remain would cause the grains to lump together.

These kilns are large horizontal circular units approximately 6 feet in diameter and about 30 feet long. They are mounted on a gentle slope and as they turn, sugar tumbles and rolls until it passes out the lower end. Hot dry air is passed through to remove all excess moisture. From here the sugar passes to the sifters located on the floor below.

Sifters

There are six sifter units receiving sugar continuously. The sugar passes over vibrating screens of various sizes: cube sugar is taken off first; then the sugar is graded for coarse, medium and fine sugar, each of which is a quality item.

The three grades of sugar are then packaged at the second floor or placed in refined sugar bins, which are new and are located at the fifth floor level in a new structure, built beside the panhouse on the warehouse roof. The refined sugar bins for finished sugar are located in a new Butler-type construction. It is a complete system by itself, with automated flow of material in and out of the bins and tied in with the bulk load-out system installed.

A panelboard located in this building is controlled by the operator who sets up the routing elements by means of switches and plugs: the bin that is to be emptied, the flow procedure, and the railroad or tank truck that is to be loaded. Circulation from bin to bin can also be arranged. Screw conveyors and elevators are operated to carry out this operation.

The sugar is screened to remove fines and lumps before it is weighed and passed out for shipping. The tanks are all permaglass type to prevent sugar from collecting and lumping on their surfaces. Sufficient circulation from tank to tank is maintained to prevent lumping.

Powdered sugar is derived from dry sugar from the kilns which is fed into hammermills which crack and pulverize the crystals until they pass through a very fine screen. It is then packaged, ready for shipping.

As noted earlier, many commercial customers use sugar syrup instead of the granular product. This saves them the work and time required for melting. Approximately 25 percent of the product output is in this form.

This product does not go to the panhouse for the final process. Instead, char liquor is press-filtered after treatment with activated carbon to produce essentially a water-white liquor ready for shipment to various customers. This amounts to approximately half a million pounds of syrup per day from this plant alone.

Steam is used to help clean out the system and melt off any sugar; steam, combined with acids is employed to wash away all impurities periodically.

Miscellaneous equipment

Oil tank barge	Tied up at dock. Unloads enough oil daily to fill the main supply tank for the plant.
Main oil tank	50,000 gallon capacity. Filled each day when operative. Pumping equipment on dock moves the oil through piping to the storage tank.
Powerhouse	Oil fired boilers use approximately 1,300 gallons per hour.
Ship (sugar)	One ship unloaded each week, with approximately 11 million pounds of raw sugar per ship.
Warehouse	Holds 500 million pounds 700 feet long Four to five weeks supply maintained Raw sugar keeps there for months without deteriorating

4.2.3 Personnel (normal)

The personnel listed here cover all phases of plant management and operation. The plant works on a three shift basis which means that only one third of the operating personnel are in the plant at any one time during the 5-day work week.

Office, engineering & research	110
Packaging	90
Shipping	60
Storage of products	30
Panhouse operation	100
Filterhouse operation	50
Melthouse operation	15
Raw sugar storage	25
Refined sugar storage	5
Stevedores	30
Steam plant & enginehouse	25
Guards	10
Maintenance	100
Total	650

4.2.4 Shelter (within plant)

The sugar refinery has no provision in the plant for a fallout shelter area, and no plans or consideration have been made for this purpose. There are, however, basement areas that could be converted into fallout shelters. Some construction would be necessary to make these areas suitable for the purpose. The shelter would need a capacity great enough to take care of the operating personnel as a minimum requirement, as these are the people who will shut down the plant. Operating personnel on the two shifts not working at the time would be absent, and therefore would find shelter at home or elsewhere. Some capacity should be provided to protect non-operating personnel who could not evacuate to community shelters or to their homes in time for satisfactory protection.

4.2.5 Shutdown and startup (normal)

Shutdown normally starts at the beginning of the process by stopping the supply. As each unit runs out of process material, it is stopped and cleaned. It is necessary to clean carefully all equipment that handles or processes the sugar to prevent any contamination of the product for human consumption. With the shutting down of steam and electric requirements, the power plant will automatically reduce its operation to a minimum until load is required again. Some steam is usually maintained to supply heat to tanks of syrup that must be kept in liquid form. If the shutdown is for a longer period and all syrup has been removed from tanks, then the steam plant can be shut down completely. Ordinarily the plant is never shut down to this extent. A sudden total shutdown would leave the equipment without cleaning and the syrup would solidify everywhere. This would necessitate a considerable amount of work heating and melting the syrup in pipes and tanks.

To start up the sugar refinery process, raw sugar must be available in quantity sufficient to maintain normal production, and steam must be available to supply the necessary heat.

Raw sugar is then introduced to the melt house, and process equipment is placed in operation, each unit consecutively as needed. Steam is introduced to melt the raw sugar into syrup, and the syrup must pass through the bone char filters before going to the panhouse. These are slow processes, and several hours must elapse before the syrup is ready for the evaporation process to make sugar crystals. In the meantime, the panhouse must wait while equipment is made ready for reception of filtered syrup. Each machine throughout the whole plant is placed in operation as needed, all the way to packaging, storing and shipping.

If syrup is already in storage tanks from previous operating shifts, then production flow starts almost immediately throughout the whole process system, which is the normal daily method for production.

4.2.6 Utilities (normal)

The steam power plant uses oil from a 50,000 gallon tank, located between the dock and the steam plant, to fire the furnaces. An oil barge brings oil to the dock and fills the tank three times daily, at each work shift. When in operation, the furnaces use 1300 gallons per hour.

All electricity is supplied by the steam power plant. The steam which is required in large quantities for process purposes, is used to generate electric power first. The exhaust steam then continues on to be used for melting raw sugar and heating the syrup throughout the refining process.

Then a thousand gallons of sea water per minute are pumped from the dock area as a coolant to produce a vacuum. This assists crystallization of the refined sugar. The waste water is returned to the sea.

Pure fresh water is supplied by the city at a rate of 1,000,000 cu. ft. per week, chiefly for cleaning tanks and for diluting the syrup.

4.2.7 Repair and maintenance capability (normal)

The machine shop is a large, low building located in a central area of the plant grounds. It has a good variety of equipment for machining, welding, and repairing of all plant facilities.

There are over 100 men working in the machine shop, carrying out maintenance through the entire plant. These men are experienced in servicing all equipment used in the plant, and would be capable of the complete repair and recovery of equipment to place the refinery back into production after nuclear weapon damage up to the high blast range.

Any building repair or replacement would be carried out by contractors, as this type of work is not performed by the regular personnel.

4.3 VULNERABILITY ANALYSIS

4.3.1 Low pressure blast range 0.0 to 0.5 psi

Although a portion of the raw sugar warehouse walls would collapse, the main problems are connected with removing dust and debris from the sugar. Very little damage to equipment would result, except in the raw sugar warehouse.

Structures

Although there is considerable damage to the product in various stages of refinement, caused by glass shard missiles being scattered about the interiors of storage and processing areas, the most severe structural damage in this range would result from collapse of part of the raw sugar warehouse walls and the roof itself at 0.4 psi. Originally, the warehouse walls were relieved by 18 percent apertures but, subsequent to construction, about one-third of the windows have been bricked in. This area of the warehouse is the end located farthest away from the melthouse and the other processing areas. The weakest link structurally is the end connection system of the shear diagonals in the frame bent at each column row. Where the windows have been bricked in, these would fail inward at 0.4 psi blast overpressure. Where the windows have not been bricked in, the connections would fail at 1.0 psi.

The conveyors and bucket elevators located at dockside could suffer from this wall collapse, but since the bricked-in wall will collapse inward, the chief damage would be to conveyors and raw sugar in the interior.

At the end of the raw sugar warehouse nearest the melthouse, the elevators and conveyors are securely anchored to the melthouse wall and would not be damaged in this blast range.

Elsewhere in the plant, at 0.5 psi, glass windows would be shattered and missiles would cause breakage to equipment and contamination of product, particularly since many tanks are not kept covered.

Process equipment

Damage to process equipment in the 0.0 to 0.5 psi range would be limited to that caused by flying glass and dust. Instruments, particularly glass-covered liquid level indicators and dials, would be most susceptible to damage from missiles. The equipment located nearest to windows would naturally be the most vulnerable.

Materials and product

Most of the blast damage to sugar is connected with damage and contamination of the raw sugar. In the part of the warehouse adjacent to the melthouse, the raw sugar would be contaminated by debris, broken glass, dust, possibly by radioactive fallout, and sooner or later, by rain water.

Throughout the plant, glass particles will be scattered about and some of this will inevitably find its way into syrup tanks and storage bins.

In the portion of the warehouse farthest from the melthouse, where the walls and roof will have collapsed onto the raw sugar exposed in the two lengthwise bays of the 700-foot long building, it may not be practical to attempt to save the sugar.

4.3.2 Medium pressure blast range 0.5 to 5.5 psi

In addition to aggravation of problems created by dust and flying glass, structural damage in the medium pressure range would be fairly extensive, involving raw sugar storage, refined sugar storage, stacks, powerhouse and filterhouse. Serious damage to equipment in these buildings would result from missiles and falling masonry. Figure 4-4 illustrates damage to the refinery at 3.0 psi overpressure.

Raw sugar warehouse

At 1.0 psi or more, the entire structure will collapse inward due to failure of the end connection system of the shear diagonals in the frame bent at each column row. (Where the windows are blocked up this failure would actually occur at 0.4 psi, see 4.3.1). The ability to move the raw sugar stored inside would be temporarily lost, and rain could rule out salvage of the sugar.

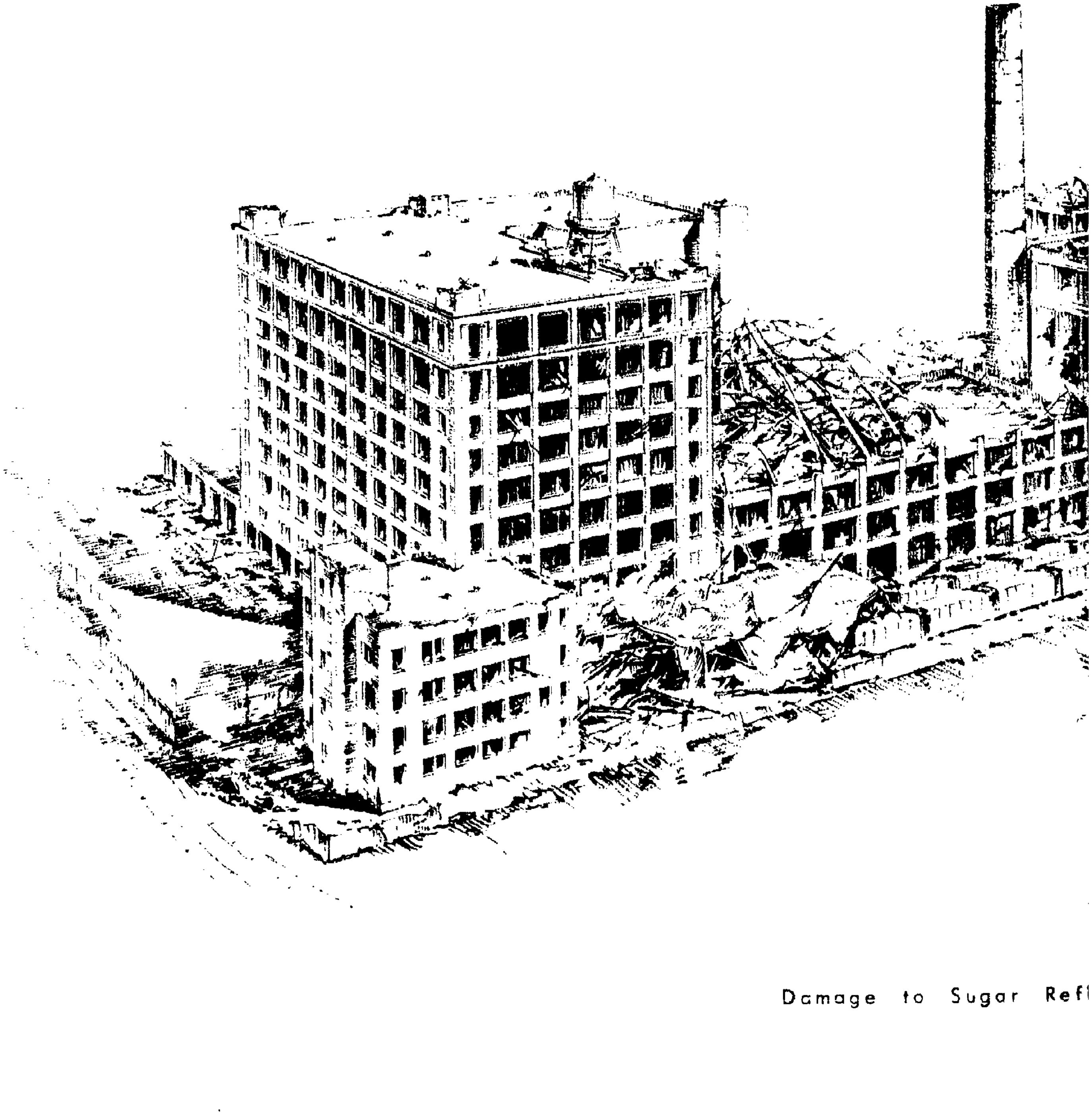
As mentioned earlier, a fire burned off the wharf side of the building a few years ago. The heat was sufficient to caramelize sugar as well, but the greatest damage was caused by firehouse water, soaking and washing away the sugar. After removing the burned building materials and scorched sugar, the remainder of the sugar was found satisfactory for use. The crane in the wharfside bay could not be used, and the other could only operate half way down the bay. A number of belt conveyor units were rushed to the scene and in a few days sugar was moving from anywhere in the storage area. Actually, no time was lost in the plant operation for lack of raw sugar. This indicates what could be done with comparable postattack failure or loss of equipment, depending on the availability of new or satisfactory material handling equipment.

Refined sugar storage

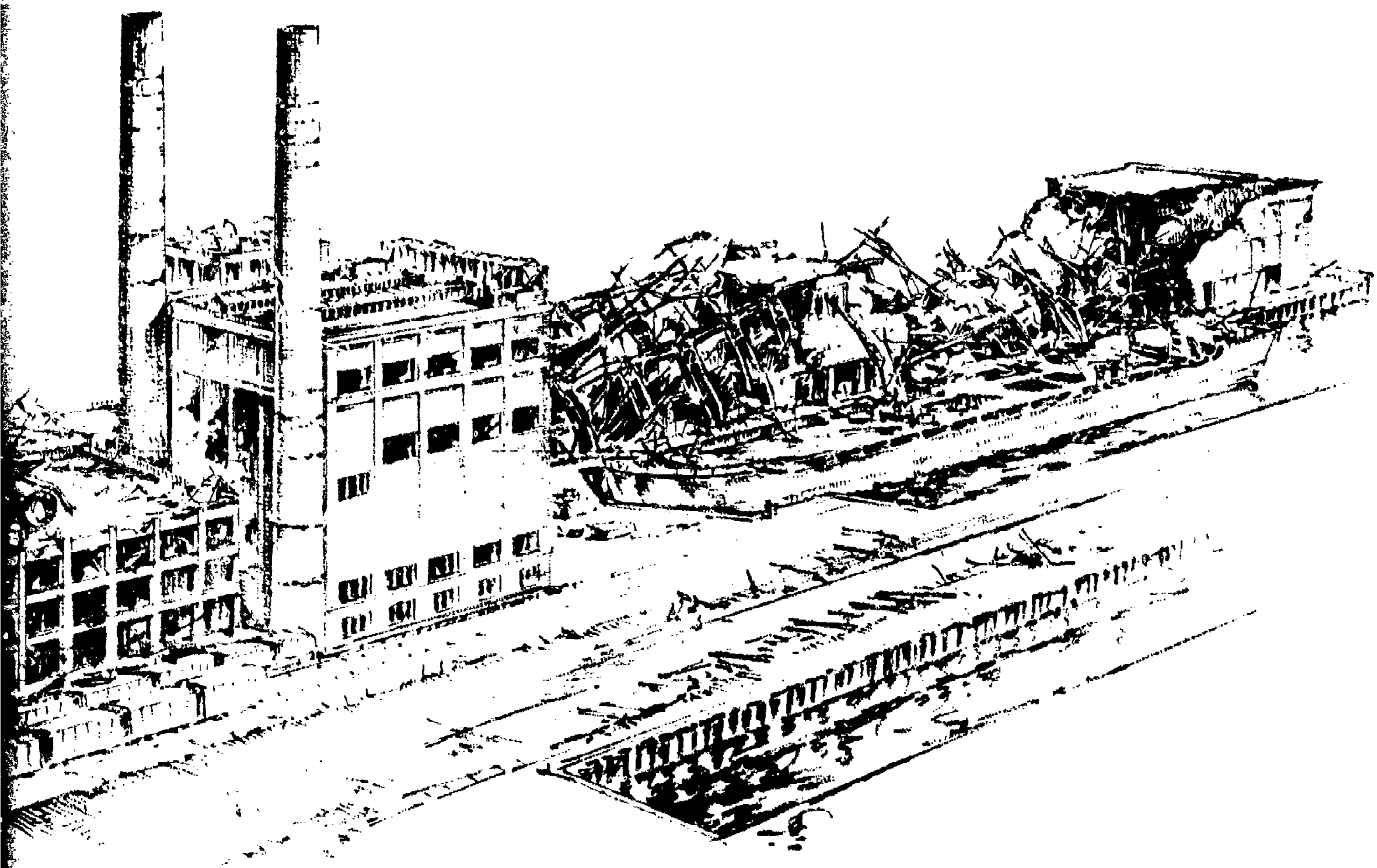
The weakest element of this building is where the column bases are anchored to the reinforced concrete roof of the finished products warehouse by means of swedge bolts. These bolts would fail in shear at slightly over 0.5 psi and cause collapse of the structure and bins onto the roof. The almost completely enclosed structure would have much greater blast resistance if the side and roof panels were blown off at less than 0.5 psi overpressure, but it is more likely that the swedge bolts will fail first. The stability of the frame and tank system is improved by an increase in the quantity of sugar in the bins, because the added mass at the core improves the resistance to overturning and has the effect of reducing the natural frequency of the system, and hence its rate of response to dynamic loading.

Panhouse

The north wall, which is without windows, will suffer some cracking at 3.5 psi, but damage will not extend to the frame. Other sides have more than 50 percent windows and will fail at much higher overpressures. The two water tanks on the roof of the panhouse, supported on a single set of columns, are primarily drag structures and would be subject to overturning, if empty, at 4.0 psi. If partially filled, however, their stability becomes greatly improved because the additional mass of the water improves the resistance to overturning, while tending to decrease the natural frequency and reduce the rate of dynamic response. If full, the failure criterion is column buckling of the supporting legs, which would occur at 6.5 psi. The tanks are normally kept full, and therefore failure in the last-named mode can be expected.



Damage to Sugar Ref



to Sugar Refinery at 3 psi Overpressure

Figure 4-4

Filterhouse

This building is similar in construction to the panhouse and is, in fact, connected to the panhouse on one side. The two are really one building, the panhouse being one wing and the filterhouse the other. The north wall is only 15 percent window area, while the other three sides are over 50 percent. Consequently, the north wall would be the most vulnerable to blast: it would crack at 4.0 psi, and there would be panel failure at 6.5 psi.

Melthouse

The construction is steel frame with 12-inch concrete walls and 16-inch pilasters. The exterior walls are 30 to 50 percent window area and would not be vulnerable to blast damage in the medium overpressure range, except for the north wall, which has no window openings and would crack at approximately 4.0 psi.

Boilerhouse

The building is a steel frame similar to the melthouse, except that the overall percentage of openings is much less, and they are concentrated at the lower stories, on the east and west. For this reason, the north and south walls would be subjected to extensive cracking and severe damage at approximately 3.0 psi, while the east and west walls could survive much higher overpressure levels.

The boilerhouse stacks can be expected to crack at 2.0 psi, and overturn at 5.0 psi; they are not, however, essential to the boilerhouse operation because the power plant has been converted to oil fed boilers, some of which have forced draft. The stacks are 180 and 185 feet high, respectively. There could be considerable damage to adjacent buildings from overturning stacks, depending on the direction of the blast and the direction in which they fall. Because of shielding from the other buildings, particularly the refined sugar warehouse, the melthouse and the powerhouse, the stacks would be most apt to collapse from a blast coming from the east. This would cause a maximum of damage because the stacks would topple to the west onto the other buildings. The high wind velocities in the range of 160 mph for a 5.0 psi overpressure blast, would convert the toppling stacks into a number of high velocity missiles which would travel further than the height of the stack itself and cause an unpredictable amount of damage. The roof of the enginehouse could be seriously damaged if the blast came from the northeast and the stack fell to the southwest.

Enginehouse

The building has 50 percent window openings all around, and except for damage caused by falling debris, would not be seriously affected in the medium range of overpressures. Some spalling of concrete and moderate frame distortion can be expected at overpressures slightly above 5.0 psi.

Process equipment

All conveyors in the raw sugar warehouse would probably be destroyed beyond repair. It might still be possible to unload sugar from a ship, directly into the melthouse, but the ship itself would be serving as a raw sugar warehouse and would be tied up for a long time.

Damage to equipment in the panhouse, melthouse, and filterhouse would primarily be due to missiles on a random basis, with equipment close to windows bearing the brunt. Purity of product would suffer.

In the boilerhouse, partial or complete collapse of either the north or south wall would shut down the refinery for an indefinite period because damage to boilers, particularly controls and instruments, would in most cases be irreparable.

Damage inside the enginehouse, if stacks fall on it, possibly crushing the roof, could also shut down the plant by cutting off power, since the steam turbines, generators, air compressors, etc. are all located here. Most of the damage here would also be to controls, instruments, piping, valves and breakers, without which the power plant could not function.

Equipment damage in the panhouse will tend to be limited by the ruggedness of the equipment. Such items as centrifuges, motors, pumps, pressure tanks for pressure and vacuum operation and open-type syrup tanks are generally heavy, well-built and can withstand a reasonable amount of abuse The effect on syrup tanks depends on how full they are, empty tanks being much more susceptible to destruction over this range of blast overpressures.

In this range, most of the damage to equipment in the panhouse, filterhouse, and melthouse will result from missiles, and the components most likely to be damaged, as stated previously, are glass instruments, test and control equipment, hydraulic and pneumatic pipe, controls and valves. The glass windows in the pan tanks, made specially for pressure and vacuum service, would not be in great danger.

Lighter types of equipment such as rotary drying kilns, sifter screen grading equipment for fine, medium or coarse cubes, sheet metal ducts, and hammer mill attachments, are quite vulnerable to damage from missiles.

In the melthouse, the raw sugar hopper and syrup tanks would be relatively undamaged if they were full.

In the filterhouse, the filter tanks filled with bone char would probably remain undamaged, although the storage facilities for bone char that have been cleaned and baked could be damaged and the char soiled. This would not substantially affect operation of the filtering system.

4.3.3 High pressure blast range 5.5 to 10.0 psi

The damage in the high pressure range would be extensive, causing wall and frame collapse in all buildings and severe damage to equipment from blast and missiles. Complete loss of product would result.

Structures

Blast incident overpressures above 5.5 psi are sufficient to cause major damage to building walls, frames, and process equipment inside. Since medium overpressures are capable of causing major, nearly complete damage to the raw sugar warehouse and the refined sugar storage warehouse, these units will not be discussed here.

The panhouse, filterhouse, and melthouse are of the same general type of construction and can be expected to respond similarly. The north walls of these buildings, the most vulnerable because of their lack of windows, would fail first, in the pressure range from 5.5 psi to 6.5 psi. The melthouse is probably the weakest of these because of its diminished horizontal dimensions. The building frames, however, is spite of wall collapse at lower pressures, would only suffer moderate damage and would not collapse unless overpressures in excess of 12.0 psi are reached.

It has already been pointed out that the water tanks, normally full, on the roof of the panhouse, can be expected to collapse at 6.5 psi, because of buckling of the supporting columns. The combined capacity of the two tanks, 40,000 gallons, means no less than 333,000 pounds of liquid, or 167 tons, not counting the weight of the tanks and structures. If this lands on the roof of the panhouse, it will go through. If the blast comes from the south it would fall to the north and drop over the side of the building to the roof of the shipping and receiving area or the refined sugar storage area.

The north and south walls of the boilerhouse, as noted in 4.3.2, can be expected to fail at 3.0 psi, but the building frame, assuming that enough of the walls remain to provide some shear-wall action, will survive overpressures in the medium range. The frames can be expected to suffer moderate damage at 8.0 psi, and severe damage at 11.0 psi.

4.3.4 Thermal radiation

The estimate of damage from thermal radiation applies to an as-yet-undamaged plant, because the thermal radiation pulse will arrive ahead of the blast pulse. This estimate is based on a 10-megaton explosion at the optimum burst height.

The areas most vulnerable to thermal radiation are the interiors of buildings, particularly offices and other areas where there are papers, curtains or other dry, combustible materials near windows. There is very little combustible trash on the grounds near the buildings and, in any event, the structures are brick and therefore the exteriors are relatively immune to damage from small fires. Other critical areas include the packaging and shipping areas in the panhouse. There are also some wooden pallets and flooring on the shipping dock which would be very apt to char, but not likely to ignite.

Many of the windows have frosted glass in the boilerhouse and elsewhere, and hence have no blinds or shades. Other windows of clear glass have blinds or shades covering them on the inside, and although these might catch fire, they would shield the rest of the area from damage. It is probable that on a clear day the blinds on the east side would be drawn in the morning and those on the west would be drawn in the afternoon, making the direction and time of attack rather significant.

In the low range of blast overpressures, thermal radiation levels will be less than 2 cal/cm^2, and the damage to this plant from thermal radiation will be negligible, no matter what the clarity of the atmosphere.

In the medium overpressure range, thermal radiation levels range from 2 to 70 cal/cm^2. At some point between 15 and 40 cal/cm^2, loose papers and newspapers on desk tops will ignite, as will blinds, window shades, and bags and cartons used for packaging. Wooden floors and sifter frames will char. The density of combustible materials is not sufficient to cause fire spread, however.

In the high range of overpressures, thermal radiation levels up to 300 cal/cm^2 are possible. The charring of wooden frames will be severe, but they will not ignite. Boxes and cartons will burn, and in turn will ignite others if they are stored too closely to each other. A fire could, therefore, start in the packaging area and the office building. The fire fighting system depends on the water tanks mounted on the roof of the panhouse, backed up by a steam-driven pump in the boilerhouse. There are no automatic sprinkler heads, but fire hoses are strategically located around the plant.

Negligible fire spread will occur before the blast wave arrives. In the high overpressure range, blast damage would cause loss of steam, and together with loss of the water tanks on the panhouse roof, would knock out the firefighting capacity of the plant. Hence, any fires that started could possible spread through the plant, but this is unlikely due to the relative scarcity of combustible materials and was therefore not considered in making the repair estimates.

4.3.5 Fallout radiation

If there is fallout in the area, following a blast overpressure greater than 0.5 psi, it will find its way into most of the ground areas of the plant that are near windows, because all glass will be shattered. Basement areas and rooms near the center of buildings will be relatively free of fallout radiation.

Raw sugar in the raw sugar warehouse will be contaminated, unless it can be covered before the fallout arrives, as discussed in 4.3.1. It is quite possible that there would be time to take preventive measures against fallout before it arrives, and this would certainly be feasible if blast damage were not extensive.

Refined sugar or sugar in process will only be affected if it is in uncovered tanks. The refined sugar storage system is completely enclosed and should offer fairly good protection against contamination from fallout.

Much of the syrup is in open tanks and would be vulnerable to contamination. Normal techniques of processing would remove almost all radioactive contamination, however.

4.3.6 Shutdown

In the case of a crisis, the plant could be shut down almost immediately and left without any damage to machinery or equipment. The heated vats of syrup would cool gradually, all pumps would be stopped and the boilers turned off. This would allow everything to come to a standstill and some syrup, as it cooled, would solidify in tanks and piping.

Syrup is graded in consistency; a mixture of 90 percent sugar and 10 percent water for example, is called 90 brix syrup. Usually any syrup below 65 brix will remain a syrup when cooled, while a syrup above 65 brix will solidify, if not maintained at 120°F to 180°F. Above 180°F, the syrup will burn.

Tanks with high brix content are usually emptied and all piping cleared out before a weekend shutdown, to prevent any accidental cooling and solidifying in the equipment. In cases of emergency, where immediate evacuation is necessary and the plant is neglected long enough for solidification to take place, a melting procedure would be necessary. Tanks and pipes could be sufficiently heated by steam hoses to melt all sugar, and allow the process freedom to flow again.

4.3.7 Bottlenecks and weak links

The plant is an unusually stable structure. The production can carry on until rather high blast pressures are experienced. The first failure that may reduce or stop production would be the collapse of the raw sugar warehouse structure at or above 2.0 psi. This would only effect production for as long as it takes to build or supply a new means of providing the melthouse with raw sugar. This may not be a difficult problem, but construction depends on the availability of materials.

A more serious problem would be failure of the steam power plant at over-pressures of 3.0 psi or more. At this point, the brick walls on the north or south will crack. Higher pressures will increase this cracking, to the point where the walls will collapse. Since the water and fuel pipes running to the furnaces and boilers are attached to the wall, the latter's collapse will break them and this, in turn, will halt the furnaces. But repair or replacement of the piping need not be a lengthy process, and there could well be no major delays until the stack falls at approximately 5.0 psi.

4.4 RECOVERY

4.4.1 Summary of damage

The following tables, 4-1 and 4-2, summarize damage to structures and processing equipment.

4.4.2 Spare parts and cannibalization

A good stock of spare parts is maintained in this plant at all times to take care of regular repair requirements. However, after a nuclear blast many parts may be damaged or broken that are not normally needed as spares, and these will have to be supplied by the factories that make the machines, which may take considerable time. Some machines will be damaged more than others and parts could be cannibalized from them to complete the recovery of other units. As parts are repaired or supplied later, more units can be brought into production. Some relatively undamaged units could be removed from one badly damaged plant and used to help another plant get into production at an earlier date. This will work where standard machinery is concerned, but a great majority of the facilities in the plant are tanks, piping, heat exchangers, and custom-made equipment that would have to be replaced or repaired by the machine shop or maintenance men in the plant.

4.4.3 Initiating emergency operations

Following a blast, it will be necessary to inspect for damage, and plan the order of work required for recovery. It may be necessary to delay all work for a period of time during heavy fallout, but as soon as radiation drops to safe levels, it would be advisable to repair items that would place the plant in operation with the least delay. This will allow some processing to take place, in order to supply product demand as early as possible. Each level of blast will have its range of damage and its corresponding repair requirements.

Operation following low blast damage (0.0 psi to 0.5 psi)

Radioactive fallout may prevent recovery work from being initiated immediately but as soon as conditions permit, cleanup can begin. Glass particles may be scattered throughout the area and some will inevitably find their way into syrup tanks and storage bins. Meticulous cleaning will be necessary to make sure no glass or foreign matter remains in the finished product. Then the complete refining process can be placed in operation and sugar refined as usual.

Once the plant is in operation, damaged areas can be repaired and recovered; glass windows replaced, the outer half of the warehouse rebuilt, equipment repaired and the raw sugar reclaimed. For the immediate postattack requirements, raw sugar can be supplied from the intact portion of the warehouse and production maintained.

Table 4-1 Summary of Damage to Structures

Pressure psi	Raw Sugar Warehouse	Refined Sugar Storage	Boiler House Stack	Boiler House	Pan House	Melt House	Filter House	Engine House	Water House	General
0.1	Glass Cracking	Glass Cracking		Glass Cracking	Glass Cracking	Glass Cracking	Glass Cracking	Glass Cracking		Missile dam. To gages & dials
0.4	Solid Walls Collapse									Contamination of raw Sugar in warehse.
0.5	Glazing Shattered Glazed walls	Glazing Shattered Frame fail		Glazing Shattered	Glazing Shattered	Glazing Shattered	Glazing Shattered	Glazing Shattered		Contamination of refined Sugar.
1.0	Glazed walls									
2.0	Collapse		Cracking							
3.0				N&S Brick Walls failing						
3.5					N. Brick wall Cracking					
4.0					Roof see Water tower	N. Brick wall Cracking	N. Brick Wall Cracking		Empty Overturns	
5.0			Overturns							
5.5					N. Brick Wall failure					
6.0								Reinf. conc. Col. spalling		
6.5						N. Brick Wall rupture	N. Brick Wall rupture		Full steel Cols. failure	
8.0				Stl. frame Moderate Damage						
9.0								Reinf. conc. Frame failure		
10.0				E&W walls Rupture						
11.0				Stl. frame Severe dam.		Stl. frame Mod. dam.				
12.0					Stl. frame Mod. dam.		Stl. frame Mod. dam.			
13.0						Stl. frame Severe dam.				
14.0					Stl. frame Severe dam.		Stl. frame Severe dam.			

Table 4-2 Summary of Damage to Processing Equipment

Structural	Critical Overpressure psi	Process Equipment
Glass cracking	0.1	Dust throughout plant
Raw sugar warehouse - solid walls collapse	0.4	Material handling equipment damage
Glazing shattered - refined sugar storage frame failure	0.5	Meter glass & gauges cracked etc. by missile damage. Screens cut - glass in process equipment - some storage tank damage - conveying equipment damaged - cleaning equipment damaged
Raw sugar warehouse - glazed walls collapse	1.0	Material handling equipment damaged - weigh scales damaged
Boiler stack - cracking and falling bricks	2.0	Stack connections damaged - boiler equipment damage
Boilerhouse N & S walls fail	3.0	Boilers damaged - controls - meters & equip. damage- repair & replace
Panhouse - north brick wall cracking	3.5	Piping & tanks damaged & dirty - controls & equipment damaged
Melthouse - north brick wall cracking	4.0	Piping & tanks dirty & damaged - equipment & controls damaged -
Filterhouse - north brick wall cracking		piping & tanks dirty & damaged - char handling equip. damaged -
Water tower (empty) overturns		piping & connections damaged - equipment below - possible damage
Stack overturns	5.0	Connections to boilerhouse damaged & other possible damage
Panhouse - north brick wall failure	5.5	Piping tanks & controls to pan units damaged
Enginehouse - reinf. conc. col. spalling	6.0	Missile damage to controls and equipment
Melthouse - north brick wall failure	6.5	Controls & centrifuges damaged - piping & tanks damaged -
Filterhouse - north brick wall failure		Piping and tanks damaged controls & equipment damaged
Water tower (full) Steel columns fail		Piping & connections damaged Other damage from tower falling

Table 4-2 Summary of Damage to Processing Equipment (Con't.)

Structural	Critical Overpressure psi	Process Equipment
Boilerhouse - steel frame moderate damage	8.0	Boilers, controls & equipment damaged
Engine house - reinforced concrete frame failure	9.0	Equipment & controls damaged
Boilerhouse - E & W walls rupture	10.0	Boilers & auxiliary equipment damaged
Boilerhouse - frame severe damage	11.0	Piping, boilers & equipment demolished
Melthouse - frame severe damage		Equipment demolished
Panhouse & Filterhouse - frame moderate damage	12.0	Equipment demolished
Pan-Filter & Melthouses - frame severe damage	13.0 & 14.0	Equipment demolished

Operation following medium blast damage (0.5 psi to 5.5 psi)

Any blast of 1.0 psi or greater will cause the complete collapse of the raw sugar storage building. The debris will have to be cleared away and temporary conveyors installed to move the raw sugar to the melthouse. Operation could be initiated and continued while the building was being rebuilt. It would be desirable to cover the raw sugar as soon as possible to protect it against the rain.

Blast above 3.0 psi will cause failure in the north and south walls of the boilerhouse. The piping instruments, and furnace damage should be checked and repaired immediately to place the boilers in safe operating condition. The walls could be repaired after production was reestablished.

Blasts of 4.0 psi and more will cause walls of the panhouse, filterhouse and melthouse to start cracking and the damage to process equipment will depend on how much failure takes place. Repairs could be made to the damaged equipment by the plant maintenance group. Parts could be repaired in the plant shop or replaced by new ones. Cannibalization of units would probably not be necessary over this range of damage.

The stacks will overturn near 5.0 psi and may cause damage to buildings below depending on the direction of fall. With forced draft fans, the tall stack is not necessary for operation of the boilers, but it will be necessary to rebuild or replace some portion in order to carry away hazardous fumes to the air above the plant.

Maintenance personnel and operators of equipment would be called upon to do all all the recovery work in this range and are generally qualified to handle all repairs to recover operation. Outside contractors can be called in to do the building repair work without interfering with the refining operations in the plant.

Operation following high blast range (5.5 psi to 10.0 psi)

Beyond 5.5 psi, the plant would undergo the following damage in addition to that suffered in the low and medium ranges.

All brick walls will tend to rupture and fail in this range, causing damage from falling and flying brick. When the water tower collapses, it will in all probability crash through the roof and add to the structural damage. Some buildings will collapse completely and will have to be rebuilt. Building contractors will be needed, first to remove the rubble, and then to initiate new construction, rebuilding, and repairing as soon as possible.

Much of the equipment would need major repair or replacement and this work would have to accompany construction as soon as the rubble is cleared, the equipment located and the damage determined. A considerable amount of cannibalization may be necessary in making process units available to start production at an early date.

As soon as the buildings are cleared and there is sufficient construction to support and protect equipment, processing units can be repaired and placed in operation.

The water tanks' main function is to supply a large volume of water for sprinkler system needs and peak volume demands for process water. They are fed by city mains. Under emergency conditions, the plant could operate without these tanks if city water were available.

The steam power plant will have to be rebuilt and repaired in order to obtain the steam so necessary for processing. Electric power generation is also important but, under emergency conditions, power lines could be connected to a power utility to initiate operation before the electric generators are repaired.

The steel building frames of the melthouse, filterhouse and panhouse remain in reasonably satisfactory condition throughout this range, making it possible to recondition the main process line fairly rapidly, depending on the condition of the equipment.

4.4.4 Shortcuts

Sugar refining improves flavor and appearance but does not add any chemical or nutritional benefits, which is to say that uncontaminated raw sugar is perfectly good to use as is, with no refining at all. It has a mild molasses flavor, is somewhat moister and stickier than the familiar brown sugar, and comes in sizes ranging from fine grains to lumps twice the size of the conventional sugar cube. It is the standard sweetener in many developing areas which may export raw sugar without importing refined sugar in return.

Partial refining offers a wide spectrum of shortcuts in the area between raw sugar and the completely refined product, and the amount of refining would depend on the type and extent of damage to the processing equipment in a given factory or refinery. If only the Revere melthouse were to survive in operable shape, raw sugar could be made into syrup for commercial or other large-scale uses. If, in addition, the filterhouse survived, the syrup could also be filtered, and if the pan units in the panhouse were intact, they could be used to obtain crystalline sugar which could be cubed if the drying kilns were destroyed. Or production could be concentrated on brown sugar, which requires no kiln drying, sifting, or grading.

While they cannot process each other's raw materials, beet factories and sugar refineries both refine raw sugar, and it would be possible to switch raw sugar supplies from one kind of plant to the other, if one were damaged.

If the electric generators were damaged it would be advisable to bring in electric power lines from the utility company and provide power early, without waiting to have new equipment supplied or trying to rush repair work that should be done in a careful, painstaking manner.

The stacks need not be as high as the ones presently in use. It is quite possible to build shorter and less bulky stack and still maintain the necessary draft for these furnaces, inasmuch as forced draft fans are now in use. Use of reinforced concrete or a steel stack rather than brick, would greatly reduce construction time.

City water is connected to this plant and used throughout for processing requirements. This would supply all the water needed for initial stages of recovery, and the water tower could be rebuilt at some later stage when the demand became greater.

The collapse of the raw sugar warehouse could delay operation of the plant while debris was cleared and construction could provide new means for handling and conveying raw sugar to the melthouse. The plant could obtain conveying equipment to transport the raw sugar directly from the ship to the melthouse, bypassing storage. This would allow refining to continue while the warehouse was being rebuilt and stored sugar recovered.

4.4.5 Utilities

Water supply

Both fresh and salt water are used. Pure fresh water is used in processing sugar and for boiler feed water; seawater is required in a heat exchanger to create a vacuum for the final pan operation in sugar crystallization.

The fresh water is supplied by the city and is available through regular underground piping which should remain intact and ready for use as long as there are any process facilities in condition to use it. Without this pure water, no process operation could be performed.

The supply of seawater depends on pumping equipment in the plant and electric power to drive it. The pumps are very heavy units and would probably be ready for operation whenever the processing equipment is ready.

Electric power

Electric power is an integral part of the plant system. The electricity is turbine-generated as a byproduct of the steam required in the manufacturing process. Rather than have electrical system repairs delay plant operation, it would be advisable to run power lines to the nearest available utility, to supply immediate needs. As mentioned in the preceding section, this would assist the recovery of the plant during the reconstruction period as well as initiate production at the earliest possible time. In a time of prolonged preattack crisis, it would be prudent to have power lines installed to such plants, preferably in two opposite directions, to increase the probability of one surviving. These could be quickly connected to speed recovery.

Fuel supply

All heating is supplied by the steam power plant and oil is the fuel used. A storage tank of 50,000 gallons capacity is located underground in the wharf area. The oil is brought in to the wharf in tank barges, and the storage tank is pumped full three times each day at the beginning of every shift even though the full tank would last approximately 35 hours under normal operating conditions. If dock pumping facilities were damaged, an oil tanker could extend a hose connection and fill the storage tank directly, or even supply the furnaces if the storage tank needed repair. However, this part of the system is likely to survive in operating condition even after the processing equipment has been damaged and found inoperable, indicating that plant operation will not be held up for lack of fuel.

4.4.6 Repair required to resume normal operation

Low blast damage range

Recovery in this range does not involve many difficult problems and the time delay to recover operation is exceptionally small.

Other than the raw sugar warehouse, very little structural damage takes place in this range. For any blast above 0.1 psi, windows would have to be checked and replaced wherever necessary. Above 0.4 psi, the outer half of the raw sugar warehouse would collapse, and contractors would have to be obtained to remove the debris and rebuild this section completely. The raw sugar should be covered as soon as possible to protect it from loss due to weather. Boats would have to unload through the half of the warehouse next to the melthouse, where equipment and space would be still intact.

Process equipment would remain intact except in the outer half of the warehouse. The conveyors and material handling equipment in that area would be demolished, and these would have to be replaced as soon as the structure is rebuilt.

The problem of protecting the raw sugar in this area from fallout, rain or wind would be the initial undertaking. If the area could be covered by a tarpaulin before fallout arrives, much of the raw sugar contamination would be avoided. The filtration process would remove dust, fallout and glass particles from the sugar, but high radiation levels at the filters could provide an additional hazard to operating personnel in the early postattack period.

The cleanup of debris, to save as much of the sugar as possible, may require more labor than would be worthwhile. In the warehouse, bucket or scoop type tractor loaders, portable conveying equipment, hand shovels and wheelbarrows will all be required to separate the sugar from the debris.

In the portion of the warehouse farthest from the melthouse, where the walls and roof will have collapsed onto the raw sugar exposed in the two lengthwise bays of the 700-foot-long building, it may not be practical to attempt to save the sugar. For the immediate postattack period, sugar can be taken from the intact portion of the warehouse, or from supplies brought in from elsewhere. This portion of the warehouse and the sugar in it could be left as is for the time being, or at least until the radioactivity from fallout has decayed to a point where the hazard to personnel would not be a factor. At such time, the warehouse structure could be rebuilt and the sugar could either be discarded or cleaned up, depending on availability of supply and economic considerations.

Medium blast damage range

All parts of the plant will receive some damage in this range, with reconstruction and repair of buildings involving the greater part of the time and work required to recover. Processing equipment will sustain some damage but not to the extent of being irreparable. Equipment in the raw sugar warehouse will be badly damaged and some replacements may be necessary. Repairs can generally be made in a reasonable period of time and recovery initiated.

Raw sugar warehouse

At any overpressure of 1.0 psi or greater, this entire structure would have to be rebuilt. A contractor should start work as soon as the fallout hazard is reduced to a safe level. The collapsed structure should be removed first and the raw sugar material salvaged, before new construction could commence.

New conveying and handling equipment will be required to replace all destroyed items. The weigh scales and government inspection equipment would have to be replaced for final operation after recovery. Temporary conveyors could be used to move raw sugar to the melthouse from the warehouse and from the boats until recovery was complete.

Refined sugar storage

The storage building will tend to deform and some structural work will be necessary when the swedge bolts fail around 0.5 psi. If the tanks were full of sugar, stability would be improved and repairs would be minor near 0.5 psi, but pressures above 1.0 psi would tend to collapse the whole structure and to turn over the tanks. This would require the rebuilding of the whole facility, and a contractor would be required.

The augers and conveying equipment are of aluminum throughout, to help in maintaining cleanliness. Even the tanks are aluminum, lined with glass. If badly damaged, these items would require complete replacements. The shaker screens are very fragile and would have to be replaced.

Loss of the refined sugar storage area would not shut down the refinery, but it would create considerable inconvenience and inefficient utilization of transportation equipment. In the six tanks, or bins, used for refined sugar storage, the sugar is continually circulated within each bin and between bins to prevent lump formation. Under emergency conditions such operations may have to be skipped, with resulting quality deterioration, before conveying to trucks or railroad cars for bulk shipment.

Panhouse

The north wall will begin to crack at 3.5 psi and will require checking and repairing if any higher pressures are experienced. Some sections could fail near the high portion of this range and would require replacing materials.

All equipment will have to be cleaned, checked for missile damage, and repaired. The equipment generally is of heavy construction and damage could be mostly superficial, such as broken glass and small pipes, damaged tubing, electrical wiring and controls. Most of these repairs could be made by the maintenance personnel. A considerable stock of material is kept on hand at all times and most of the recovery could be taken care of without any shortage or bottlenecks.

Filterhouse

Conditions here are very similar to the panhouse except that the north wall may withstand pressures of up to 4.0 psi before cracking. Beyond this, failure takes place and repairs, similar to the panhouse repairs, will be necessary. Filterhouse equipment is generally rugged and should remain intact as long as the surrounding structure does.

Melthouse

The north wall will crack with blasts near 4.0 psi, and construction problems are similar to those of the filterhouse and panhouse.

Most of the equipment here is rugged and should withstand the effects of blast throughout this range, except for the centrifuges, which are near the north wall. With a blast from that direction, the centrifuges may receive missile damage when this wall fails. The small tubing, piping, and electric controls may be damaged and it would take maintenance crews a considerable amount of time to repair and replace them. However, it is probable that the plant could carry out this service with its own personnel.

Boilerhouse

The boilerhouse structure will withstand overpressures up to 3.0 psi before any serious blast damage occurs. Above this pressure, checking and repair of the east and west walls would be necessary. An outside contractor will be needed to carry out these repairs, especially after the stacks collapse near 5.0 psi and damage becomes much more extensive.

Loss of stacks alone could be sustained, because of the existence of some forced draft units, although the presence of flue gases in the immediate plant area would create some problems.

Boiler steam is therefore required for generating power and heating. The heating is needed for the various tanks or vats of syrup, without which the syrup would solidify. The chances are that, even if repair requirements throughout the rest of the plant were fairly extensive, the time and effort to repair the power plant would be at least as great, and this would probably be the controlling feature in returning the refinery to operating conditions.

Nearly all equipment would have to be cleaned thoroughly because of the extensive penetration of dust, and this would probably involve a certain amount of disassembly.

With the cracking of either the east or west wall, equipment will be damaged by falling or flying bricks and other debris. This will become more severe as blasts approach the 5.5 psi range. At this point, instrument and control panels may be demolished, especially near the side toward the blast. Repair and replacement requirements will be quite extensive. The least-damaged should be repaired first to bring one boiler into operation at an early date.

Enginehouse

The enginehouse and equipment in it will survive this blast range with little more than superficial damage, and equipment will be usable before other parts of the plant are ready to operate. Some cleaning will be necessary and glazing will have to be replaced, but this should not delay operation.

High blast damage range

Over this range major structures will fail and collapse, requiring major reconstruction. It goes without saying that recovery of the plant and initial sugar refining will be delayed until buildings and machinery have been replaced, rebuilt, or repaired. Some building frames will suffer deformation or failure that will require basic rebuilding before equipment can be replaced. Much of the equipment will have to be cannabalized in order to place as many units on line as possible until more new parts can be obtained.

Even with unlimited amounts of building materials and construction personnel, this work would require between 60 days and 120 days of time to initiate production.

4.4.7 Substitutes

The substitution of raw sugar and partially-refined sugar for the refined product are discussed a few pages back, under "shortcuts" (4.4.4).

At the beginning of this sugar industry report, it was pointed out that sugar is an important source of food energy, accounting for 15.9% of total energy in the American diet. Nevertheless, the body can easily survive without any sugar, or, indeed, any carbohydrates at all, of which sugar and wheat are the major examples.[23] The reasons for this are that the body can use protein and fat as substitute energy sources directly and can also manufacture enough carbohydrates for its needs from other food compounds, if need be.[25]

For flavoring purposes, many calorie-free sugar substitutes are currently enjoying wide usage. The best known of these artificial sweeteners, saccharin has a sweetening power several hundred times that of sugar, by volume.

4.4.8 Increased production capabilities

The sugar refinery usually maintains a 24-hour, three shift operation over a five day week. Production could be made continuous on a seven day week basis, with a proportionate increase in production. This would no doubt increase efficiency as well, because all syrups must be maintained at process temperatures over week ends and holidays to prevent crystalization.

The equipment used throughout this plant is generally quite old. If and when material handling equipment and process equipment are modernized, production could be considerably increased within the same facilities. This, of course, would have to take place in the normal course of events and is not a consideration for the immediate postattack period.

By increasing the hours of operation and modernizing the equipment it is quite conceivable that production could be more or less doubled.

4.4.9 Estimated man-days required for repair for each level of blast pressure

These repair estimates will be found in the following charts. Following these charts is found the Recovery Chart, figure 4-5, which graphically presents the information contained in the repair estimates.

SUGAR REFINERY

Low Blast Damage Range 0 to 0.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
0.1	Glass cracking dust, dirt & debris	clean up	labor	10	30	300
0.4	Partial collapse of steel frame, raw sugar warehouse	clean up and rebuild structure	engineer technician labor	100	30	3,000
	glass shattered	replace glass	labor	10	30	300
			Structural			3,600
	PROCESS					
0.1	dust and fallout	clean equipment and material in process	laboratory technicians and labor	10	30	300
0.4	Glass and debris mixed with raw sugar Conveyor equipment damaged	clean debris from sugar in storage. Move sugar to clean area by portable equipment. Rearrange loading conveyors	labor laboratory technicians tradesmen	40	30	1,200
			Process			1,500
			Structural			3,600
		Total Man-Days for Low Range				5,100

SUGAR REFINERY

Low Blast Damage Range 0 to 0.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS TO INITIATE EMERGENCY OPERATION					
	Structural					
	Clean up debris			30	10	300
	Process					
	Clean equipment and rearrange conveyors			20	10	200
	Clean debris from sugar in storage			20	10	200
		Total Man-Days for Low Range				700

SUGAR REFINERY
Medium Blast Damage Range 0.5 to 5.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
0.5	steel frame anchorage of refined sugar storage	rebuild structure	engineers tradesmen laborers	10	60	600
1.0	raw sugar warehouse collapses	rebuild structure	engineers tradesmen laborers	10	60	600
2.0	brick wall of boiler-house & stack show cracking	check and repair	tradesmen labor	5	60	300
3.0	north & south walls of boilerhouse collapse inward	rebuild walls	engineers technicians tradesmen labor	100	60	6000
3.5	north brick wall of panhouse cracking	check and repair	tradesmen labor	20	60	1200
4.0	north brick walls of melt house and filter house cracking	check and repair	tradesmen labor	40	60	2400
	water tower (empty) overturns	rebuild	engineer tradesmen labor	20	60	1200
5.0	stacks overturn	rebuild with reinf. concrete		30	60	1800
			Structural			14,100
	PROCESS					
0.5	refined sugar storage collapses on bins which are 1/2 full	check bins repair and/or replace augers, conveyor chutes, weigh scales, screens	tradesmen labor	10	60	600
2.0	brick wall of boiler-house & stack shows cracking	falling brick and missile damage to equipment	tradesmen labor	2	60	120
3.0	north & south walls of boilerhouse collapse inward falling brick & missile damage	repair and/or replace meters gauges, piping & equipment	labor tradesmen technician	10	60	600
3.5	north brick wall of panhouse cracking missile damage from brick & mortar	clean up check & repair equipment repair piping clean out tanks & equipment	labor tradesmen	10	60	600

SUGAR REFINERY

Medium Blast Damage Range 0.5 to 5.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS (Continued)					
4.0	north brick walls of melt house & filter house cracking. missile damage	clean up. check & repair equipment. repair piping clean out tanks & equipment.	labor tradesmen technicians	20	60	1,200
	water tower (empty) overturns	repair piping & connections	labor tradesmen	20	60	1,200
5.0	stacks overturn	rebuild connections to boilerhouse	labor tradesmen	10	60	600
			Process			4,920
			Structural			14,100
		Total for 0.5 psi to 5.5 psi				19,020
		Total for Low Range				5,100
		Total Man-Days for Medium Range				24,120

SUGAR REFINERY

Medium Blast Damage Range 0.5 to 5.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
0.5	clean up debris at refined sugar storage			4	25	100
3.0	clean up debris			4	25	100
5.0	rebuild portions of stacks			40	25	1,000
	Process					
3.0	repair missile damage to equipment in boilerhouse			8	25	100
3.5	repair equipment in pan house			24	25	600
4.0	repair equipment in melt house and filter house			40	25	1,000
5.0	rebuild stack connection to boilerhouse			24	25	600
		Total for 0.5 to 5.5 psi				3,500
		Total for Low Range				700
		Total Man-Days for Medium Range				4,200

SUGAR REFINERY

High Blast Damage Range 5.5 to 10.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
5.5	north brick wall of panhouse fails	rebuilt wall	tradesmen labor	20	60	1200
6.0	reinf. conc. columns engine house show spalling	check and repair	engineer tradesmen labor	20	60	1200
6.5	north brick walls of melthouse and filterhouse fail	rebuild walls	tradesmen labor	40	60	2400
	steel columns of water tower (full) fail	rebuild	(same as empty) (at 4.0 psi)			
8.0	steel frame of boilerhouse shows moderate damage	check and repair	engineer tradesmen labor	70	60	4200
9.0	reinf. conc. columns of engine house collapse	rebuild	engineer tradesmen labor	40	60	2400
			Structural			11,400
	Note: At 10 psi or above it is considered uneconomical to repair the plant.					
10.0	east & west walls of boilerhouse fail					
11.0 12.0 13.0 14.0	steel frames show severe damage					

SUGAR REFINERY

High Blast Damage Range 5.5 to 10.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS					
5.5	north brick wall of panhouse fails	check clean and repair equipment	technicians tradesmen labor	24	100	2400
6.0	reinf. conc. columns engine house spalling some missile effects	clean, check and repair	engineer technicians tradesmen labor	18	100	1800
6.5	north brick wall of melthouse and filterhouse fail	check clean & repair equipment	technicians tradesmen labor	42	100	4200
	steel cols. of water tower (full) fail	new tank as considered at 4.0 psi but more damage	tradesmen labor	6	100	600
8.0	steel frames of boilerhouse shows moderate damage	all equipment inside damaged extensive repairs etc. to equipment	engineers technicians tradesmen labor	60	100	6000
9.0	reinf. conc. cols. of engine house collapse	all equipment inside damaged extensive repairs-dismantle clean check out operations	engineers technicians tradesmen labor	60	100	6000
			Process			21,000
			Structural			11,400
			Total for 5.5 to 10.0 psi			32,400
			Total for Medium Range			24,120
			Total for High Range			56,520
10.0	boilerhouse collapse	all equipment ruined				
11.0-14.0	steel frames in various buildings show severe damage	all equipment ruined				

SUGAR REFINERY

High Blast Damage Range 5.5 to 10.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS TO INITIATE EMERGENCY OPERATION					
	Structural					
5.5	clean up debris at:	pan house		4	50	200
6.0		engine house		4	50	200
6.5		melt & filter house		8	50	400
		boilerhouse		6	50	300
8.0		engine house		4	50	200
	Process					
	clean and repair equipment at:					
5.5		pan house		16	50	800
6.0		engine house		16	50	800
6.5		melt & filter houses		32	50	1,600
		boilerhouse		54	50	2,700
8.0		engine house		36	50	1,800
		Total for 5.5 psi to 10.0 psi				9,000
		Total for Medium Range				4,200
		Total for High Range				13,200

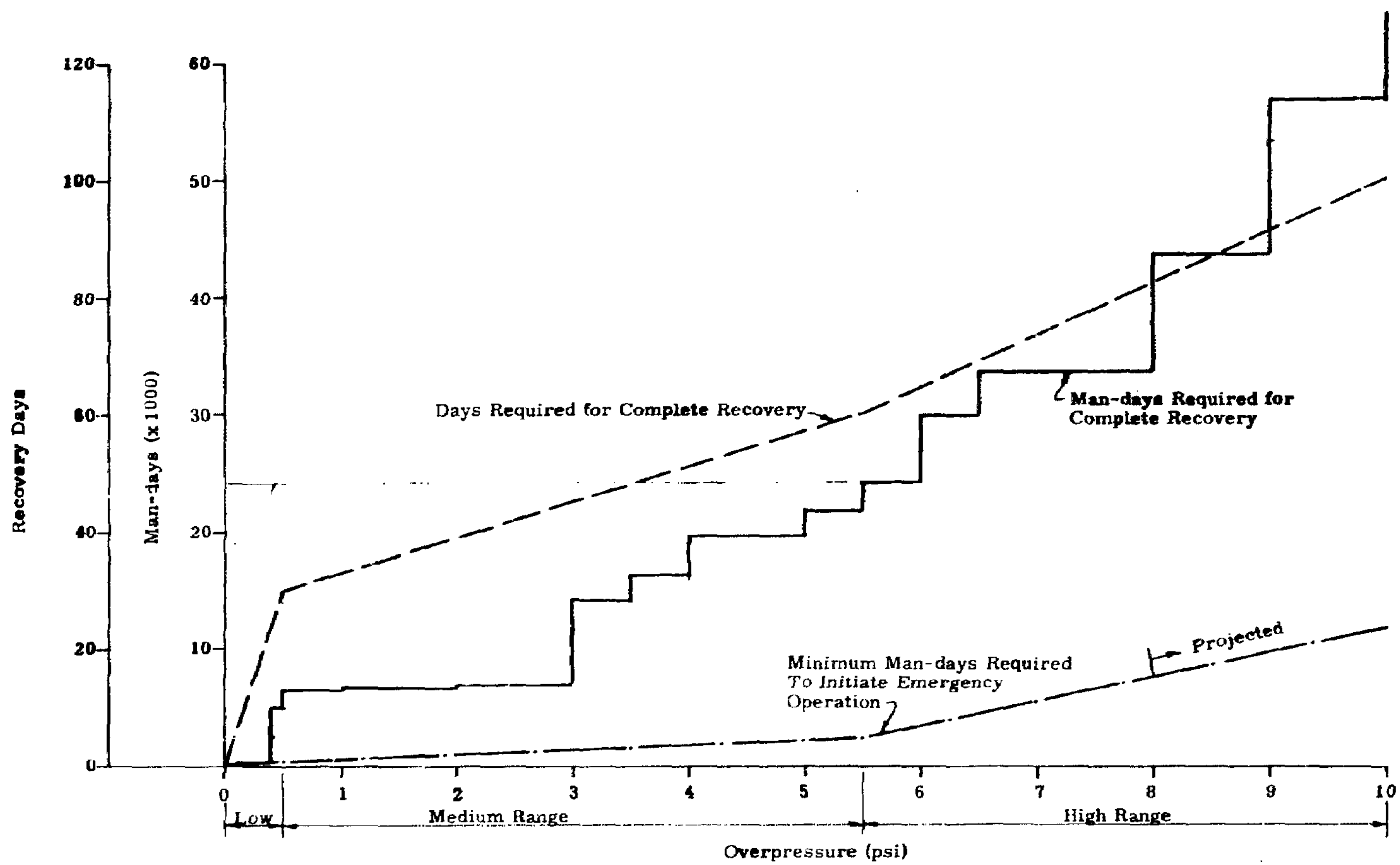


Figure 4-5 Recovery Chart - Sugar Refinery

4.5 CONCLUSIONS

The Revere Sugar Refinery is old, with most of the buildings of heavy, rugged construction. One exception is the raw sugar warehouse with a portion that fails before all the windows fail. This would delay the unloading of ships when the remainder of the process could be operating.

Sugar can be used in any stage of refinement, from raw sugar to refined finished product, and still have equal food value.

Therefore, adequate supplies of sugar, in some of its many stages of processing and refinement, could be available when required, if shipping can maintain the source of supply. If not, whatever amount of domestic (beet sugar) production is available could be supplemented by artificial sweeteners such as saccharin. In terms of energy requirements, substitutes such as other carbohydrates, edible oils and fats, wheat, bread and many others abound.

5. CITRUS FRUIT AND FRUIT JUICE INDUSTRY

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5. CITRUS FRUIT AND FRUIT JUICE INDUSTRY

5.1 REVIEW OF THE INDUSTRY

5.1.1 General

The citrus fruit industry was selected for study for several reasons. It is an important component of the overall fruit and vegetable category, with a combination of the problems present in fresh, canned and frozen foods production. In addition, since citrus fruit and tomatoes supply 34.1% of the nation's vitamin C, the citrus industry was felt to be quite important to the postattack diet. However, in the course of the investigation, it developed that concern with vitamin C proved to be somewhat unwarranted, as is discussed below. The industry production is also more concentrated, geographically, than any other, hence potentially more vulnerable to nuclear attack.

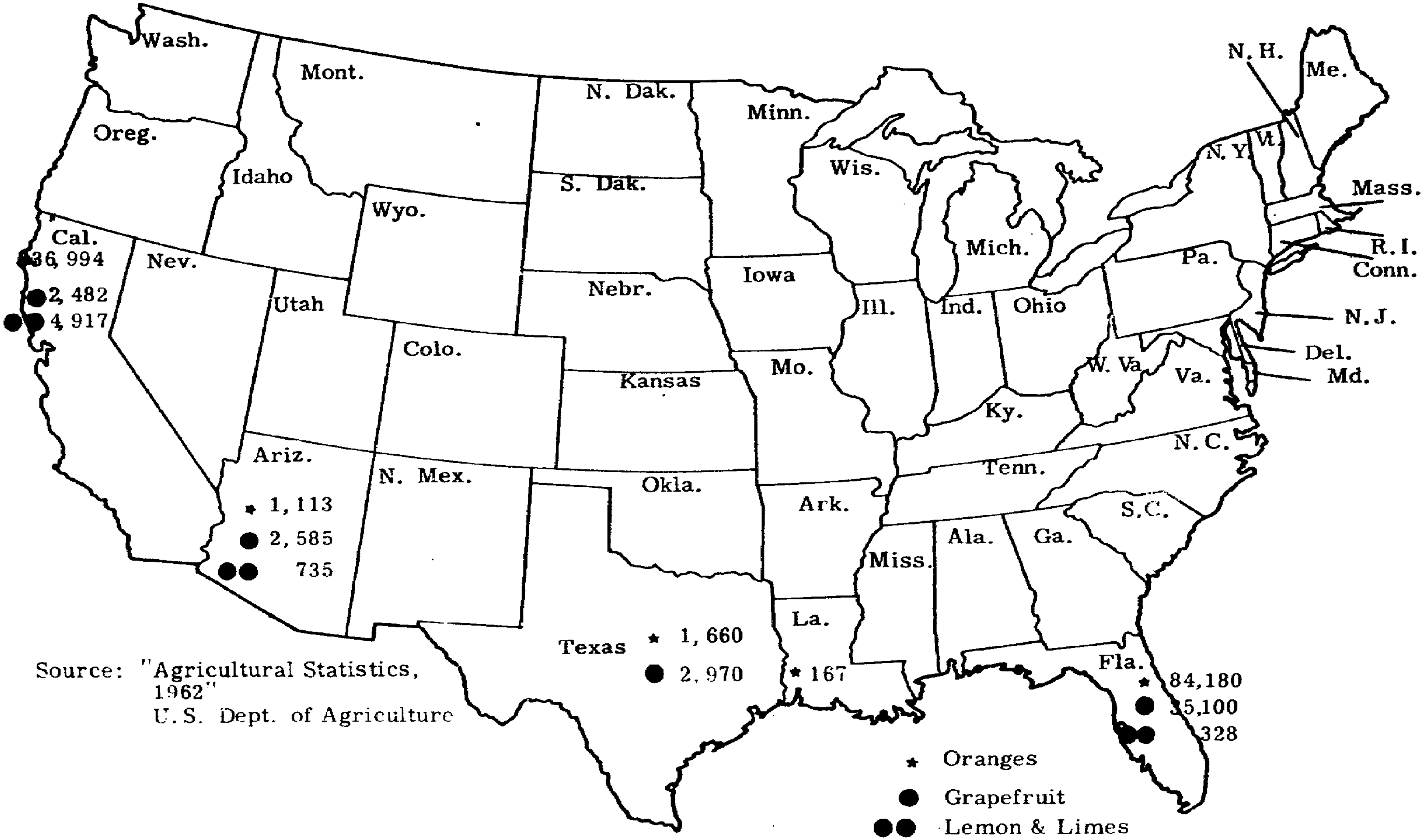
In order of crop size, the leading citrus fruit producing states are:

1. Florida
2. California
3. Texas
4. Arizona
5. Louisiana

Production for the 1961-1962 season for all citrus fruits was slightly over 202 million boxes. For a breakdown by states and types of fruit, see figure 5-1. Box sizes vary. For example, the Florida State Code defines a standard box of fruit as 90 pounds of oranges and tangelos, 85 pounds of grapefruit and 95 pounds of tangerines. The other states have their own standards, but there is reasonably close agreement on oranges: Texas, Florida and Louisiana, 90 pounds; California and Arizona, 75 pounds.

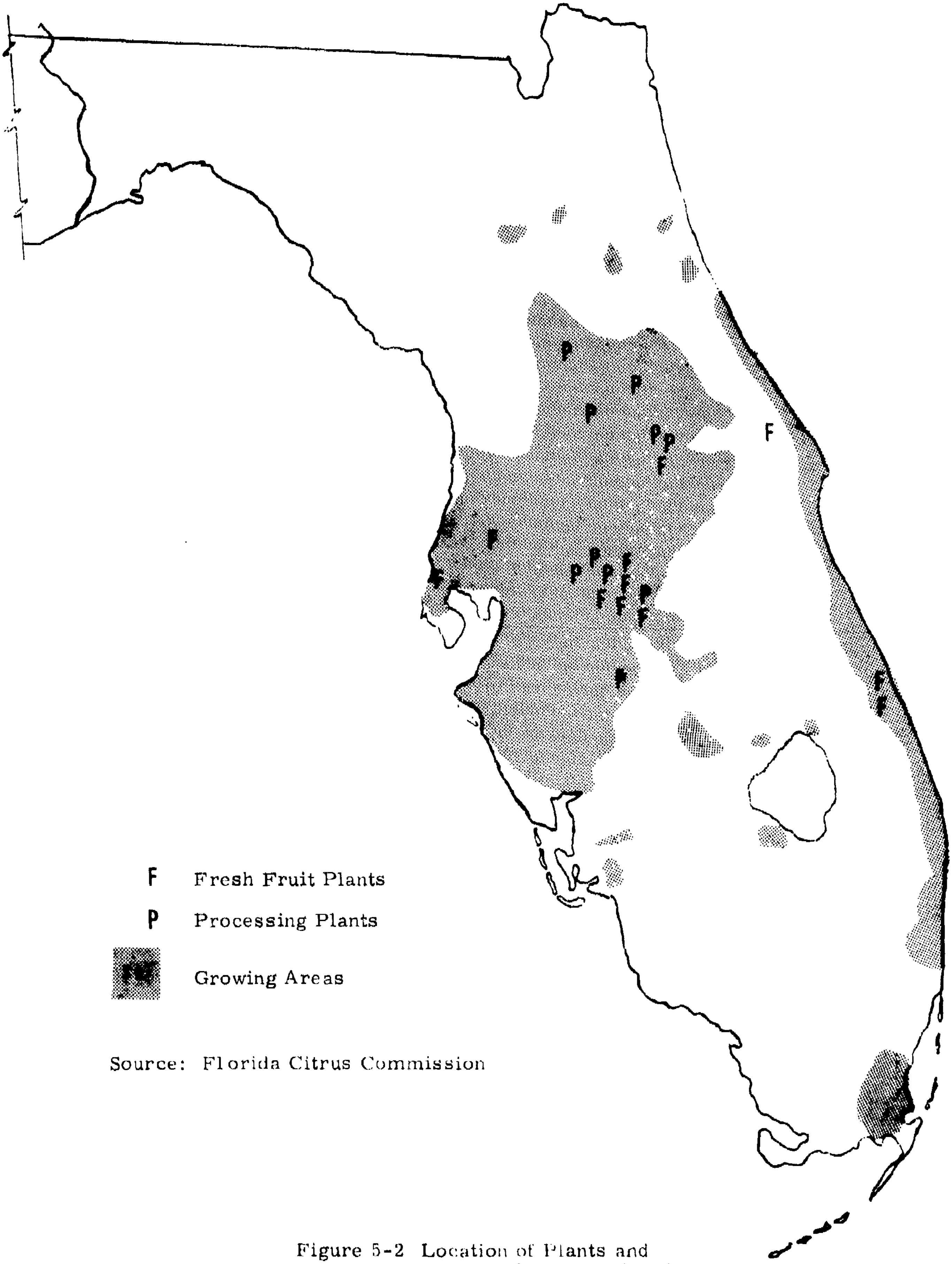
Citrus fruit were grown as early as 1579 in Florida, and the state presently accounts for 76% of total U.S. production. It may be seen from figure 5-2 that most of this industry -- both groves and processing plants -- is concentrated in a relatively narrow band in the center of the state. The industry, then, is rather vulnerable to attack because of this geographical concentration. In terms of nutrition, however, the loss of Florida production would not be as serious as it might appear. While citrus fruits are the largest single source of the nation's vitamin C (ascorbic acid), this vitamin abounds in many other fruits and vegetables and is, furthermore, easily and inexpensively synthesized.[4]

The various varieties of Florida oranges are picked from September through July, and consist of both seeded and seedless oranges. Throughout the 1961-62 season in Florida, about 18% of the orange crop was marketed as fresh oranges, and the remainder was processed for juice. The 1961-1962 season saw the production of 116 million gallons of frozen concentrate which, since its initiation in the 1945 - 1946 season, has become the citrus industry's most important product.



Source: "Agricultural Statistics, 1962"
U.S. Dept. of Agriculture

Figure 5-1 Citrus Fruit Production, by States
(Thousands of Boxes) 1950-59 Average



Source: Florida Citrus Commission

Figure 5-2 Location of Plants and Growing Areas in Florida

5.1.2 Location of groves and processing plants

Figure 5-3 breaks down processed juice production by state and type of fruit. Of the five producing states, only California and Florida have large citrus crops, and oranges are by far the most important fruit in both. The principal differences between the two leading states are that California produces few grapefruit, while Florida grows some limes but virtually no lemons. Figure 5-3 also shows canned (single strength) and concentrated juice production, by states.

5.1.3 Types of fruit juice

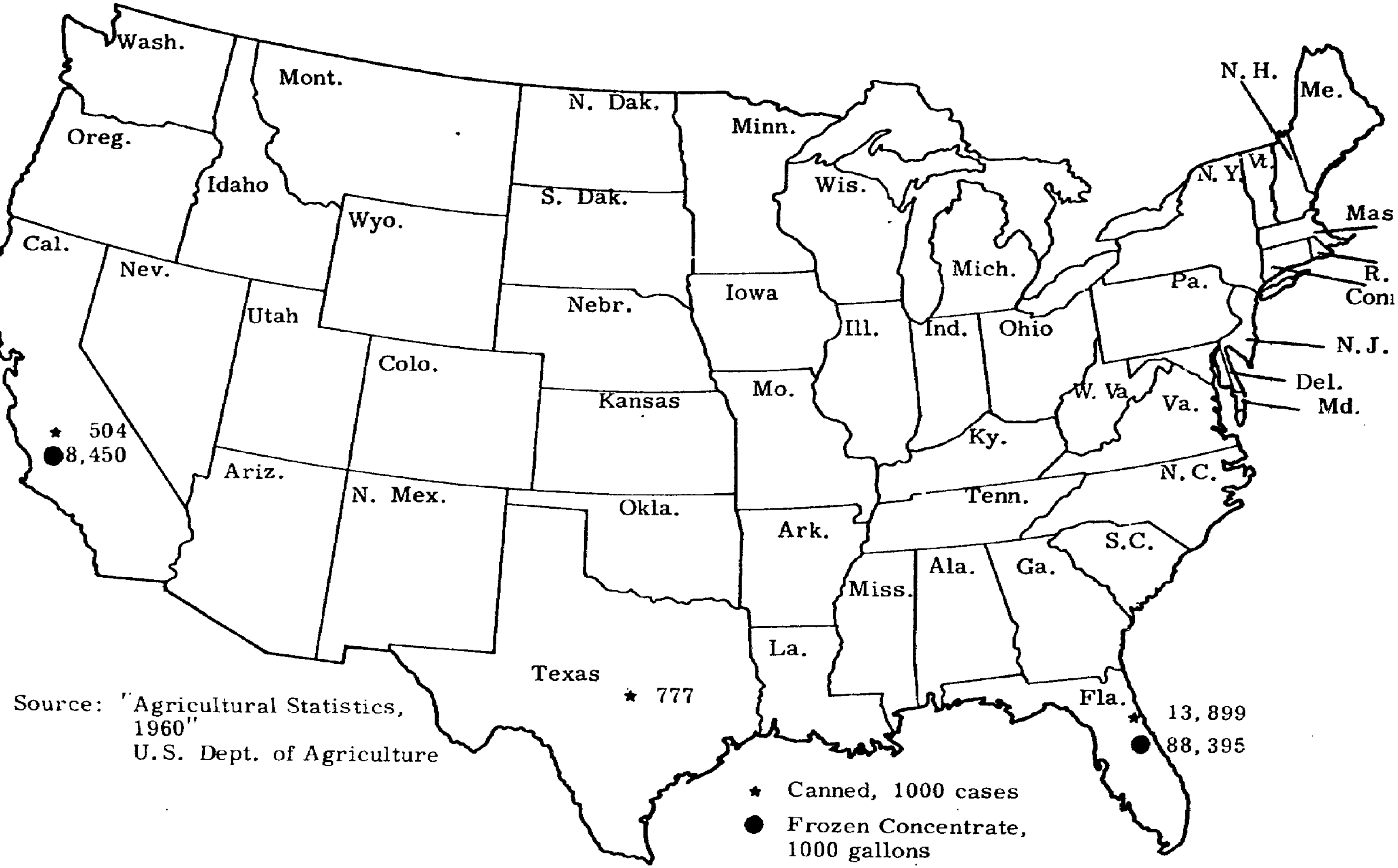
Orange juice is available in several forms:

1. Frozen 42^{o}Brix concentrate is the familiar frozen product that is reconstituted by the addition of water in a three-to-one ratio, and represents the largest single form of juice consumption. The term "Brix" refers to the percentage of solids by weight.

2. Hotpack concentrate is pasteurized by heat when packed, hence keeps indefinitely without refrigeration. Like the frozen concentrate, it is reconstituted with water. The flavor is inferior to that of the frozen concentrate, and is similar to "canned" (single strength hotpack) juice. It is sold chiefly to the institutional market and is not particularly significant in terms of volume. However, the product could have important applications in a postattack milieu, as is discussed in (4) below.

3. Chilled juice is fresh, single strength (12^{o}Brix), and may or may not have preservative such as benzoate of soda added. It is packed in paper cartons, usually quart size, and is kept constantly refrigerated. It has superior flavor and requires only rudimentary processing -- it is simply squeezed and packed -- but these postattack advantages are more than offset by its poor keeping qualities.

4. Fruit drinks are single-strength, fruit-flavored beverages in 46-ounce cans ("Hi-C" is an example) usually containing added sugar, water and ascorbic acid (vitamin C). Like hotpacked single strength (below), fruit drinks require no refrigeration, a possible postattack advantage. A nationally-known brand of fruit drinks is processed at a second plant owned by this company, which is also located in the central Florida area. The drinks come in several flavors and are manufactured in two steps: first, as a concentrate that is stored until needed and second, the single strength consumer product made by "cutting" the concentrate with water, adding sugar, then packing it in 46-ounce cans. Because they are hotpacked, the products require no refrigeration and will keep indefinitely, although there is some flavor loss after a month or so. The significance of this canning operation, in the postattack context, is that under certain conditions it might prove of benefit to hotpack 42^{o}Brix concentrate in the large, 46-ounce cans now used for the fruit drink. For example, if the cold-storage warehouses at the first plant were so badly damaged as to endanger the barrels and cans of frozen concentrate stored there, the product could be transferred to the second plant (assuming it to be undamaged), melted down, and hotpacked as 42^{o}Brix concentrate. When needed, the concentrate could be diluted three-to-one, just as the frozen variety is, and consumed. There would be some flavor loss, as with all "canned" juices, but little loss of nutrition. And its keeping quality would not depend on



Source: "Agricultural Statistics, 1960"
U.S. Dept. of Agriculture

Figure 5-3 Canned and Concentrated Citrus Juices Production by States, 1960 refrigeration, which could be in short supply in certain disaster areas.

Unlike the 6-ounce frozen concentrate cans, which are enameled, the fruit drink cans are paper-labeled as they come off the line. This could be an advantage in the event that production were switched to hotpacking of orange concentrate, since it would be far simpler and quicker to print new paper labels than to manufacture enameled cans that properly identified the contents.

5. Single strength hotpack is the "canned" product, common 20 years ago, but now largely displaced by frozen concentrate.

6. Whole oranges and other citrus fruit have reasonably good keeping qualities and represent an alternative to processed juice in an emergency, provided suitable transportation were available to handle the greatly increased bulk of whole fruit, as compared with the canned concentrate that would yield an equivalent amount of juice.

In 1961, per capita consumption of citrus products of all kinds broke down as follows:[2]

fresh	30.5 lbs.
canned segments	2.6 lbs.
canned juice	13.7 lbs.
frozen concentrate	32.2 lbs.
total	79.0 lbs.

A better idea of the relative importance of concentrate may be had by multiplying the 32.2 lbs. by four, to get the approximate weight of reconstituted juice.

5.1.4 Transportation

Although transportation was not studied, the number of trucks and/or railroad freight cars to be used will depend on whether whole fruit or canned concentrate is shipped under the postattack conditions. In normal operation, fruit comes in by truck, and frozen concentrate is shipped out by both truck and rail.

5.1.5 Trends

A new technique at the plant in Plymouth, Florida involves the rapid evaporation of water with the use of one vacuum evaporator and the introduction of a relatively high temperature instead of passing the juice through several sequences of vacuum evaporators.

Another trend is the removal of water from the juice by a freeze-drying process. Research is being performed at the plant visited and at present is a trade secret. It is the opinion of the engineers at the plant that this process will be more economical than existing water-removal processes and that flavor will be improved.

There is no readily-discernible overall trend in the industry. Following a phenomenal growth in the early 1950s, frozen concentrate consumption has varied little in recent years, as is also true for canned (single strength), chilled juice, and whole (fresh) fruit.[25]

5.2 ORANGE JUICE PROCESSING PLANT

5.2.1 General description

Two plants of a leading juice manufacturer were visited in central Florida. The company has requested anonymity in this report. The description which follows applies primarily to a plant producing frozen concentrated juice, with some additional data applying to the second plant which cans non-frozen "single-strength" fruit drinks in addition to frozen concentrate.

The frozen concentrate plant, see figure 5-4, consists of a group of buildings located near a highway and a railroad siding. The buildings include wooden structures for unloading the fruit and for initial storage, and concrete block buildings for extraction and processing. Some outdoor processing facilities are present, primarily in the feed mill portion. Frozen fruit storage warehouses, several of them quite large, maintain a temperature of 10°F, regardless of ambient temperature, which during the summer regularly exceeds 90°F. Two well-known brands of orange juice are produced at this plant; one brand has a small amount of pulp returned to the finished product to give it a more "real" texture, while the other does not.

Extractors

Equipment used includes extractors which squeeze the juice from the oranges. Two types are used: the FMC type and the Brown Citrus Machinery type, and both are leased. The FMC type uses a squashing principle whereas the Brown Citrus Machinery type uses a rotary juicer technique. Both types are rugged and not easily damaged.

Electric power requirements

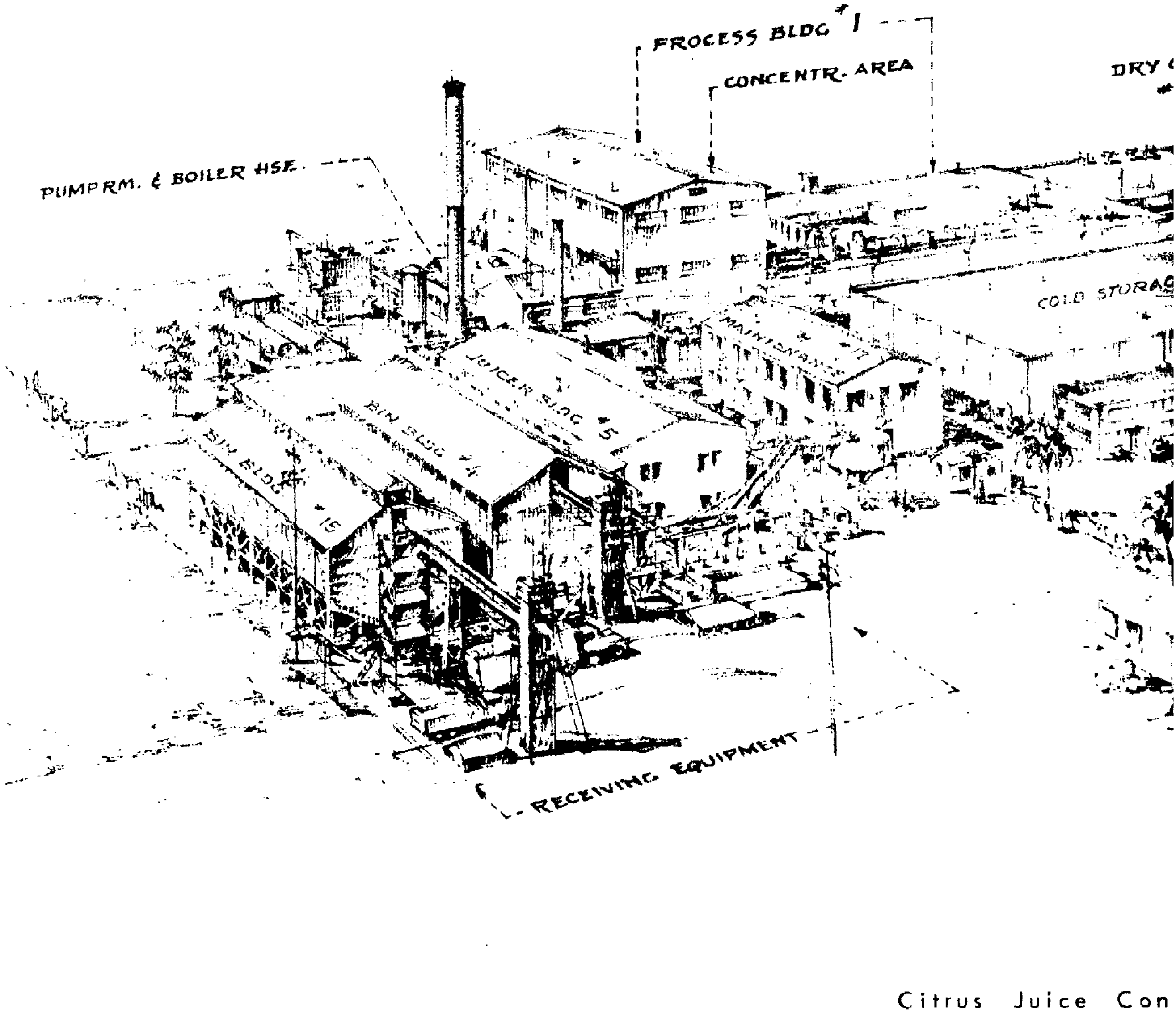
Electric power is used at 220 volts, 440 volts, and 110 volts. The steam requirement is 36,000 lbs per hour at 240° C., generated from either natural gas or bunker fuel oil.

Refrigeration

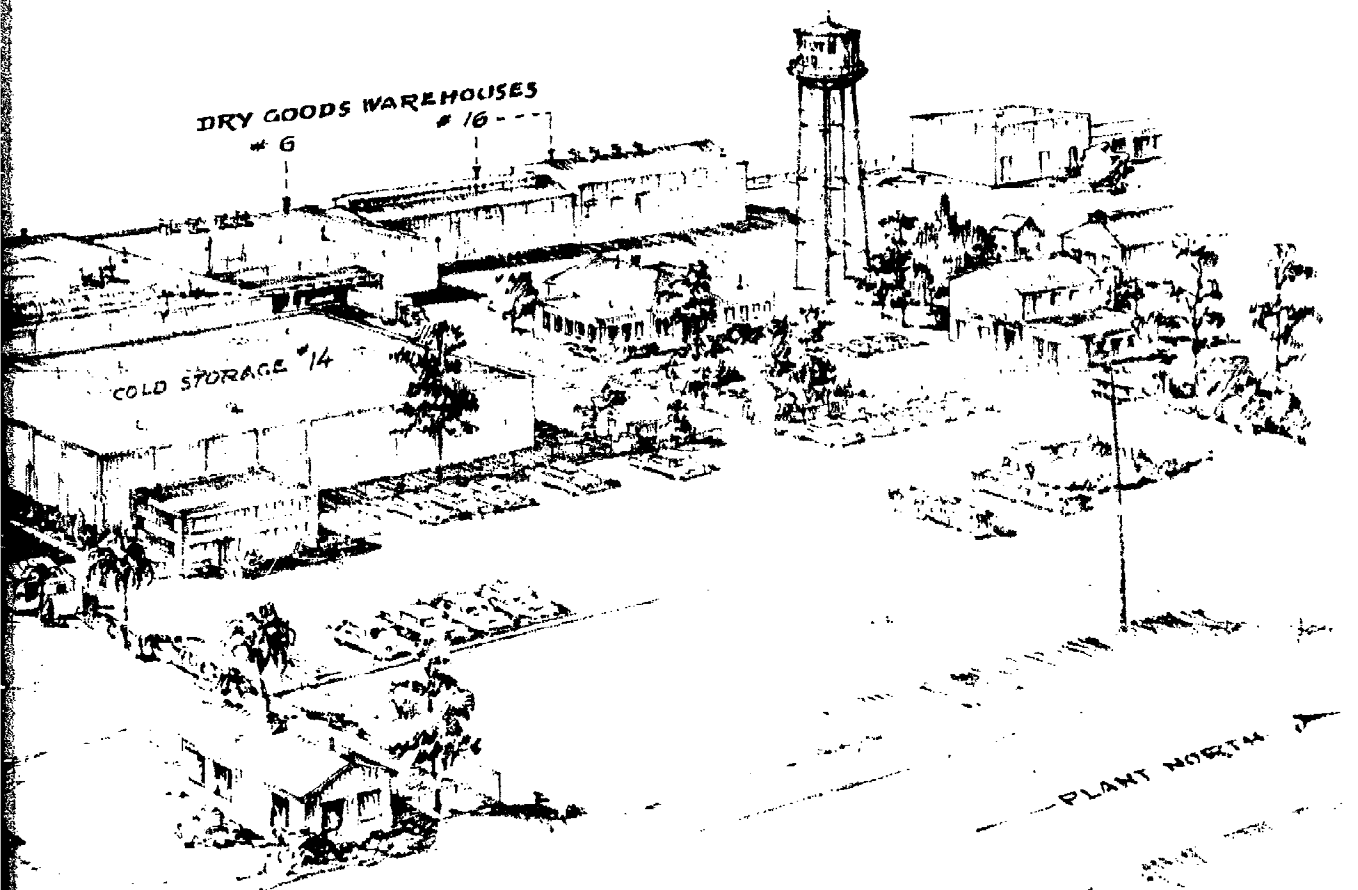
Design of the floor provides 0.0431 BTU per hour per square foot per inch of thickness. The roof is rated at 0.0301 BTU per hour per square foot per inch. Building E warehouse has 35,000 sq. ft. designed for 18.8 tons of heat loss. Refrigeration involves 12,000 BTU per hour and the heat exchangers are gasoline and diesel powered. When trucks or cars are used for shipment, the interior temperatures are lowered before they are loaded.

5.2.2 Operation

Operations are normally conducted on a 24 hour-a-day basis during the season, which runs from approximately December 1 through June 1. During the remaining six months, the practice has been to repair the factory and repair and improve the equipment, thereby utilizing the engineers and maintenance people the year around.



Citrus Juice Con



NOT SHOWN:
FEED MILL AREA
MOLASSES EVAPORATORS
DRY WAREHOUSES #24 & 25
COLD STORAGE HOUSES #10 & 8

us Juice Concentrate Plant

Figure 5-4

Picking

The picking of the oranges represents the largest single manpower requirement in the whole operation. Picking is done by hand, using a 30-foot ladder. There are approximately 90 lbs. of oranges per box, and one man can pick about 50 boxes per day, for a total of 4, 500 lbs. The picked oranges are trucked to the fresh fruit plants and processing plants. Approximately 90% of the fruit used in the concentrate (processing) plants arrives directly from the groves. The remainder, called packing house eliminations, have been culled from oranges used in fresh fruit packing houses. These may have been eliminated for deficiencies in appearance, such as size and color, which do not affect the quality of their juice.

Unloading

The loaded fruit trucks are weighed upon arrival at the plant, and then re-weighed after unloading to determine the net weight of fruit arriving. The unloading is done automatically. The truck backs down a steep ramp, the tailgate opens and the fruit rolls out onto conveyors. The plant uses about 30, 000 boxes of oranges per day.

Inspection and grading

The fruit is held in storage following unloading, with each truck shipment confined to one group of bins, so that if the fruit is to be rejected, it can be disposed of without losing good fruit as well.

Following inspection, the oranges are passed through a fruit grading operation which separates them according to size, by rolling the fruit between speed rolls which will pass the smallest fruit into a different set of juice extracting separators. There are two additional inspections on the conveyor line: one before and one following washing.

Juice processing

As shown in figure 5-5, the juice goes from the juice extractor equipment to a vacuum evaporator. Evaporation takes place at various temperatures and by various techniques. One new technique, which may represent an industry trend, uses a very short pass at a relatively high temperature of approximately 180°F, for a short enough period of time to evaporate water but not long enough to cause any appreciable deterioration of the flavor. Another process uses vacuum evaporation, with the fresh juice passed through a sequence of evaporators to remove the water from the juice and produce a high Brix compound. The juice is then "stabilized" — or heated for a very short period of time to a relatively high temperature to destroy the enzymes present.

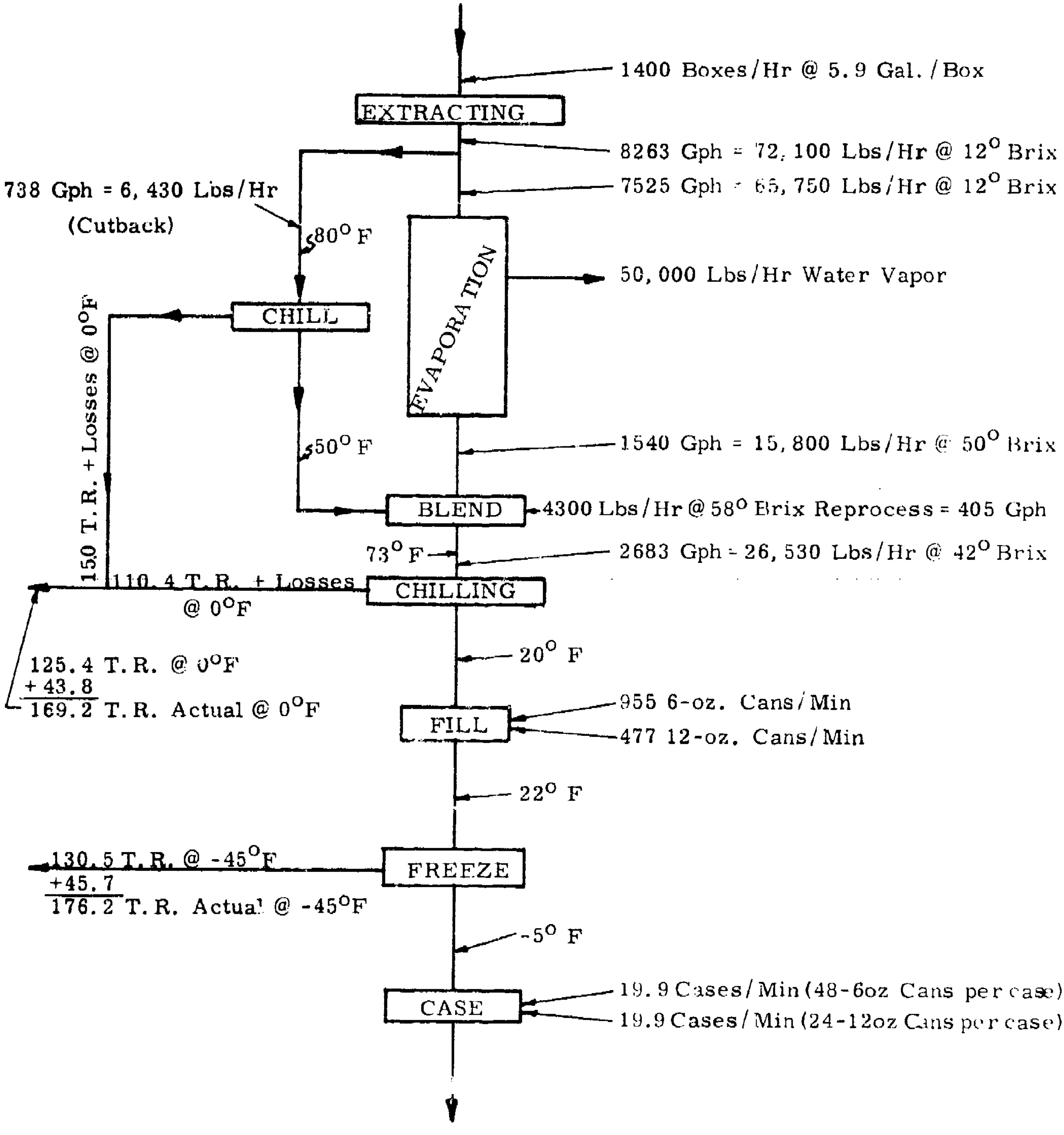


Figure 5-5 Flow Chart of Orange Juice Plant

Some of the concentrate is then stored for later use in drums in order to produce a more or less standard or constant taste throughout the duration of the production season. Other drums of concentrate held over from previous batches of oranges will be added during the blending phase. A certain amount of oil from the orange peel is also added to produce exactly the flavor desired. A small percentage of "cut-back juice", fresh single strength, is fed into this blending process to reduce the concentrated product. The 42 ° Brix concentrated product is designed to be reconstituted into orange juice by the addition of three cans of water, i.e., three parts by volume of water. Following the blending the product is fed through a product chilling area and fed from there into the cans.

Packaging

Can plants supplying the orange juice industry are operated by American, Crown and Continental Can. Experiments have been conducted in connection with other types of packaging. The steel can, ordinarily used for concentrates, costs a little less than $.02 per can. A specific quote listed was $19.85 per M, compared to which the paper container might cost something like $18.70 per M. The 6-ounce citrus can is the second largest volume of all can production: approximately 2 billion cans are used a year.

Can fillers and sealers

The can sealers are similar to those observed in many other plants, where the machines first fill the cans, then put on the can tops and seal the cans automatically. Cans are fed to the can filling and closing mechanisms by several different processes. Some of the cans come in by truck, and some by rail; some are randomly loaded, or "scrambled", and some come in on pallets. The tendency is to have most of the cans on pallets. Such cans pass through a depalletizer mechanism, which removes the cans from the pallets and lines them up single file on conveyors which take them to the can filling and closing processes. Cans that are shipped to the plant in scrambled condition are passed through a Dudley unscrambler, which aligns the cans in the right direction, makes sure that the cans are all turned open side up, and then feeds them on a conveyor over to the can filling and closing operation.

Some of the juice is fed into barrels rather than cans, for frozen storage or for shipment to other plants to be held and later to be blended with the other products. Some of the barrels also are used by restaurants and other volume users.

Blast freezing

The cans or the barrels then go into a freeze tunnel where they are blast-frozen at a temperature of -30°F. The cans come out in sequence and go into the casing operation, where they are lined up and packed into cases. The paper cases are then glued, closed and stacked on pallets and transported to the refrigerated warehouses, where they are stored pending shipping.

Storage

Concentrated orange juice is ordinarily stored at -10°F and may be held more or less indefinitely at this temperature. Storage is in leased facilities, located adjacent to the plant, where the concentrate is stored locally for a period of up to 6 - 8 months, then shipped to markets throughout the country, to meet demands. With respect to storage, at 18 to 22°F, an appreciable flavor loss would occur. Bacterial and enzyme growth do not start until 28°F is reached. In time, cans will explode due to the generation of gas by the enzymes if they are permitted to grow.

Byproducts

The principal byproduct is a cattle feed, which includes pulp, seeds and peel and is dried and made into a pellet-like material for dairy cows. It is competitive with beet pulp but not with corn pulp, and is used quite widely throughout the southeast and east. About 8 to 10 pounds of feed are derived from one box of oranges. The first step is the production of molasses, which involves taking the peel, adding lime to it, chopping it up, holding it for ten minutes and then squeezing the liquid out in a screw press.

Then the solids from the screw press go into a kiln dryer, which has an input temperature of 1,300 degrees and an output temperature of 220 degrees F. When dried, the solids contain less than 10% moisture. Fines are then pressed into pellets and added to the rest. The liquid which is squeezed out in the screw press is citrus molasses, which is quite bitter and is used for cattle feed and for the production of alcohol.

Other byproducts include oils, such as orange oil which is produced from the peel and used as a flavoring in confectionaries and cake mixes, and for perfumes.

5.2.3 Personnel

Approximately 35 to 60 employees are required for continuous flow operation. The pulp plant uses 6 to 8 persons, the juicer 6 to 10; 1 or 2 in the evaporator, and 12 to 14 in packaging. There is one man in the refrigeration plant, and three men in warehousing.

The plant operates on as many shifts as are necessary to process the incoming supply of oranges, with certain periods requiring three shifts per day.

5.2.4 Shelter (within plant)

There were no designated fallout shelters within the plant area. Drygoods warehouses could probably be used as fallout shelters if the bags of feed were stacked by a forklift truck in such a manner as to create an enclosure within the warehouse. Perhaps enough bags could be arranged to obtain a protection factor of 100 provided there was enough time to construct such an enclosure.

5.2.5 Shutdown and startup (normal)

Startup and shutdown are characteristic of the industry every six months, corresponding to the beginning and end of the growing season. When the season has ended the entire processing system is cleaned and flushed out with caustic soda. In addition, every 72 hours the low temperature evaporator is shut down in order to allow for a 4-hour cleanup procedure, after which it is put back on line and operated.

5.2.6 Utilities (normal)

Water supply

Water is supplied by 30-foot-deep wells. Water is essential for the processing system, particularly in the production of steam by three boilers, each requireing 1,000 to 4,000 gallons per hour, depending upon the demand. A considerable amount of water is required in the washing of the whole fruit prior to processing, as well as the cleaning of the plant and its equipment.

Electric power

Because electricity rates vary in different sections of the state (Florida), some citrus plants fill most of their electrical needs with their own steam generators, and others are supplied entirely by an electric utility company. The plant which is analyzed in this study is entirely dependent on an outside source of electricity.

Previous studies have indicated that electricity will generally be available through relatively invulnerable high tension transmission lines to the distribution substations under most low overpressure postattack conditions.[8] The immediate availability of electricity, then, could depend on whether or not a given plant is supplied by more than one line and more than one power station; if there are two stations, the lines are apt to run in different directions, with the probable result that if one line is destroyed, the others will be spared.

This plant is tied into two such high voltage lines; one supplies 8,300 volts and the other 12,000 volts for the motors and compressors with an aggregate of 5,000 horsepower which demand this high voltage. Either line could supply the plant's entire electrical needs in an emergency. Two-thirds of the horsepower is used for refrigerating cold storage houses and process chilling. The three 400 horsepower compressors demand 2,300 volts.

There is a transformer station on the plant property to which the high voltage lines are connected. There the voltage is reduced to the requirements of the plant's electric units, which use 220 or 440 volts, and the lighting system which is 110 volts.

Steam supply

Two steam boilers are used to supply heat for the processing operations at two different pressures to supply heat economically, depending on temperature requirements. The plant uses 36,000 lbs./hr. @ 240 psi and 10,000 lbs./hr. @ 150 psi. The boilers burn natural gas piped in from Texas by Florida Gas Company. They are also capable of burning Bunker C fuel, kept in storage tanks. Conversion from one fuel to the other is simple and is dictated by price fluctuations in the fuels.

The steam heats the orange juice to aid in evaporation and, near the end of the process, supplies the high temperature that is required for a very short period of time in the final vacuum dehumidifying stage. This last stage is heated by the high pressure steam.

5.2.7 Repair and maintenance capability (normal)

The repair shop contains the typical heavy duty and hand tools with which normal maintenance and repair is effected.

Processing equipment in citrus juice plants is constantly being updated. Maintenance and repair crews are capable of fabricating certain new equipment as well as refabricating existing equipment to obtain a processing system which is more efficient and less costly to operate. Therefore, in a postattack emergency situation, repair and fabrication of equipment could be accomplished under the supervision of the plant engineer and a member of their engineering department.

5.3 VULNERABILITY ANALYSIS

5.3.1 Low pressure blast range (0.0 psi to 0.5 psi)

At 0.5 psi, shattered glass in all windowed buildings and corrugated metal siding torn off the process building and boilerhouse will act as missiles and damage gauges, instruments, small piping and light sheet metal equipment. Glass, dust and debris will be blown into any open processing equipment and will spoil the juice.

Considerable damage will be sustained by the warehouses. Concrete block walls will fail at the upper level of this range at all the dry goods warehouses, except at warehouse No. 24 where metal siding will be torn off. Bags containing the cattle feed byproduct will be torn, spilling their contents over the area. The cinderblock walls at cold storage houses No. 8, 10 and 14 will also fail, breaking and scattering cans of frozen juice.

5.3.2 Medium pressure blast range (0.5 psi to 5.0 psi)

The following additional damage will occur in the medium range.

At an overpressure of approximately 1.0 psi, the blast will force the concrete block walls against the steel frames, causing frame failure at dry goods warehouses No. 6 and 25 and at cold storage houses Nos. 10 and 14. The corrugated asbestos roofing will be torn off the maintenance building. The concrete frame of cold storage house No. 13 will fail but at a lower overpressure than that causing failure of the walls, due to the fact that the storage house has four compartments formed by shear walls which contribute greatly to the resistance of the concrete block walls, which will fail at close to 2.0 psi.

The steel frame of warehouse No. 16 will collapse at 1.5 psi, and the corrugated asbestos roof of the juicer building will fail, thereby increasing the missile damage to equipment and contamination of fruit in process. The feed warehouse roof will be destroyed at pressures between 1.0 and 1.5 psi, and damage to the feed thereafter will depend on the weather and on the speed with which the feed is given some kind of protective cover.

The roof and walls of the process building (low bay) will collapse at 2.0 psi causing considerable damage to conveyors, can sealers, packaging equipment and refrigeration units. The quick-freeze room will also be damaged. The frame, however, will not collapse until 4.0 psi.

The water tower, if empty, will collapse in the vicinity of 3.0 psi and will require rebuilding and repiping with new components, exclusive of any equipment which is deemed salvageable after inspection. The molasses evaporator tower will also fail, creating a very messy cleanup if failure were to occur when the tank was full. Depending on the direction of the blast, the evaporator tower could survive up to 5.0 psi.

At 4.0 psi, see figure 5-6, there is general damage to the receiving and pulp handling equipment. The corner towers of the structures which support this equipment are intrinsically stronger and, because of the great variety of framing alignments, the direction of the blast will determine which structural element will be severely damaged. However, conveying and sorting equipment will sustain considerable damage at any overpressure above 3.0 psi.

The steel frame of the process building (low bay) will fail, causing damage to equipment in addition to that done by the roof and wall collapse. An independent steel frame supporting five 30-foot high evaporators in the high bay of the process building will give way, providing there is no shielding effect by other equipment. All other vats such as concentrators in this building are mounted on frames which are structurally tied into the building framework and will survive throughout this blast range.

5.3.3 High pressure blast range (5.0 psi to 10.0 psi)

At 5.0 psi, the receiving and pulp handling towers will fall, requiring the complete rebuilding of the structures and the conveying and sorting equipment. The steel frame at the juicer building will collapse, severely damaging the stairways and platforms at the juicing machines. The rigid frame at dry goods warehouse No. 24 fails, causing damage to stored material in addition to the missile damage caused by the failure of the corrugated metal siding in the low range. The frame failure of the maintenance building would demolish the small office in this building and would severely damage power equipment such as lathes, drill presses, welding machines, etc.

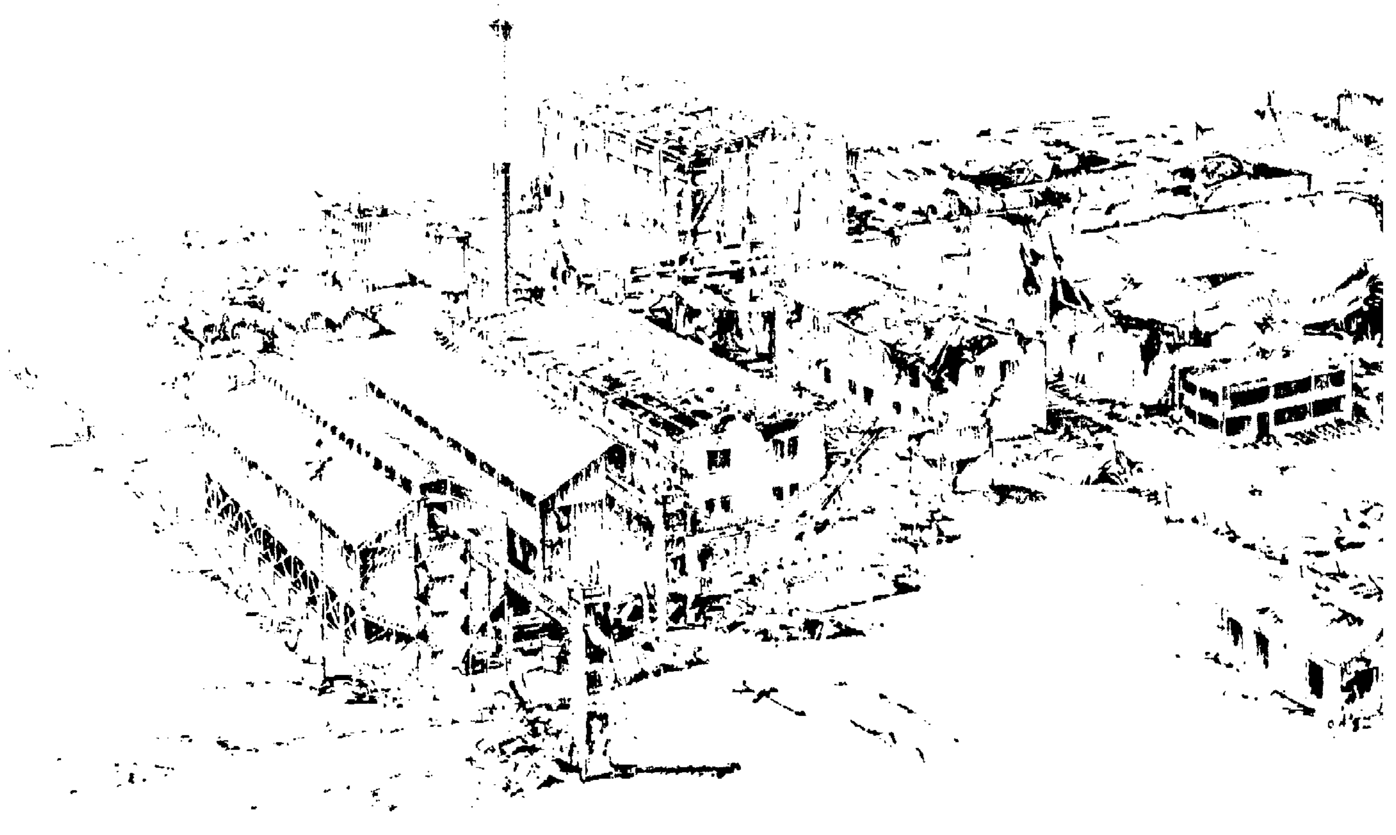
The stack will overturn and the water tower (when filled) will collapse at 5.0 psi. At 6.0 psi, the steel frame of the boilerhouse will fail, damaging the boilers and allied equipment.

Up to 7.0 psi, the frames which support equipment and are integral with the frame of the process building (high bay) will suffer moderate damage. The concentrators and evaporators are not vulnerable to direct blast effects and therefore will be undamaged up to 7.0 psi, when moderate frame failure occurs. Severe damage to the concentrators and evaporators will occur with the complete collapse of the supporting frames and building frame at 10.0 psi.

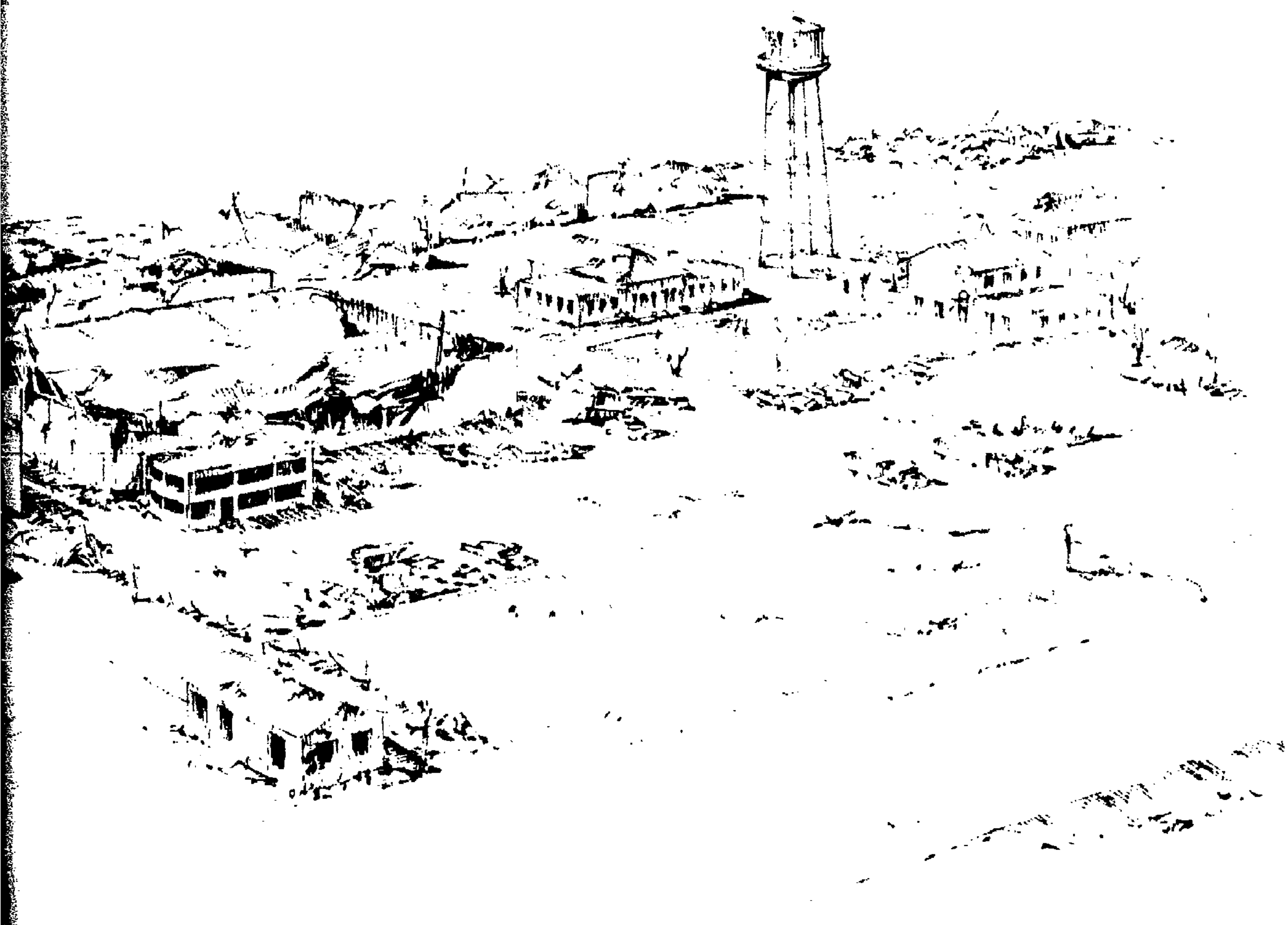
The bin buildings when empty might be subject to damage at approximately 7.0 psi by the probable failure of the exterior supporting columns. These bins, constructed of well-braced timber, are more or less open and can survive a high level of blast pressure. When full, no damage to them would be expected until a level of overpressure is reached far above that which completely disables the plant.

5.3.4 Thermal radiation

Thermal radiation could be a major hazard to personnel, but damage to the plant would be minimal. There is little combustible trash in or around the buildings; the plant is immaculate and is periodically inspected by health



Damage to Citrus Juice Plant a



trus Juice Plant at 4 psi Overpressure

Figure 5-6

officials. With the exception of the timber roof on the low bay of the process building, the buildings are constructed of non-combustible materials. The timber roof would char and its tarpaper covering would ignite, but fire would not be sustained and charring elsewhere would be improbable.

Paper (stationery, blueprints, etc.) used in the administration and engineering offices could ignite and perhaps set the building afire. However, the fire would not spread, since the office building is well separated from the plant and warehouses.

Fire danger in the plant is limited, due to excellent sprinkler systems.

5.3.5 Fallout

In addition to being a hazard to personnel, fallout could contaminate material in process, particularly at the juice extractors and the can sealers, where the juice is exposed to the atmosphere. If this equipment were not decontaminated thoroughly, the fallout would eventually contaminate the entire processing system. This would also be true for damaged equipment, such as piping, being repaired under conditions of incomplete decontamination. It would have to be thoroughly cleaned before being reconnected with whatever previously decontaminated elements of the process line may already have been restored to operation at an earlier postattack date. If the warning time were such as to permit proper shutdown, cleaning should not present a problem, as the procedures are well established due to normal cleaning at the end of each shift. The consequences of improper shutdown are discussed below.

5.3.6 Shutdown

The plant can be shut down very rapidly with no damaging effects. A shutdown every six months is normal procedure in the industry, corresponding with the termination of the crop season. In addition to this, the low temperature evaporators are shut down every 72 hours to allow cleaning and sterilizing which takes approximately four hours.

Although no damage is expected with an abrupt shutdown, a severe cleanup problem will result after a four day period. Ideal shutdown procedures in the preattack warning period would involve the flushing out of as much of the orange juice in process as possible, because maggots and bacteria would develop in four to six days, requiring a flushing with caustic soda. After one and half to two weeks, the material would harden and the cleaning task would become more difficult: it would be necessary to remove all the decayed material with shovels and then to flush with caustic soda.

Spoilage will also occur if the frozen cans of juice are allowed to remain at temperatures above 28°F, and in time they will explode due to the swelling caused by enzyme activity. The cold storage houses, if left unattended without refrigeration, would warm sufficiently to cause enzyme growth and thereby ruin the concentrate. In the case of a well stocked warehouse, this could take from three to six weeks, depending on such factors as blast damage to walls and roof, and ambient temperatures.

5.3.7 Bottlenecks and weak links

A major disaster to the Florida orange crop occured in December, 1962, when a hard freeze occured. In the 1962 to 1963 season, approximately 125 to 130 million boxes of oranges were expected, but the actual yield was only 74,000,000 boxes. In the 1963 to 1964 season, only 64,000,000 boxes of oranges were expected because recovery after a hard freeze usually takes three to four years.

Light freezes can be counteracted successfully through the use of heaters, smudge pots, and burning rubber tires. It is conceivable that radioactive fallout could coincide with a light freeze and, since personnel are required to set out and service the grove heaters, the crop could be lost for lack of a labor force, especially if the fallout prevented postfreeze picking for two weeks or more.

After a hard freeze, the fruit on a tree is still usable for the production of juice for a good many days. The tree gradually absorbs the juice in the fruit, since the cells which hold the juice are punctured by the ice crystals as they form. During the first and second week, a slight drop-off in juice content of fruit occurs. Much more occurs during the third week and fourth weeks, and the fruit becomes useless.

In juice processing, the weak links are the cold storage warehouses and the evaporators. The warehouses are severely damaged at relatively low overpressures, and such damage would endanger the stored frozen concentrate, of which there could be as much as a six months' supply, at normal rates of consumption.

Without the evaporators, no concentrated juice processing (hotpack or cold) is possible. With the evaporators out of commission, it would still be possible to hotpack single strength juice, but this would not appear to be practical in the small 6-ounce concentrate cans which the plant is set up to handle. A better plan would involve diverting oranges and/or juice (if tank cars or trucks were available) to the nearby fruit drink facility, which could hotpack the juice, either as concentrate or single-strengh, in the 46-ounce cans used there. This assumes, of course, that the fruit drink plant is relatively undamaged.

5.4 RECOVERY

5.4.1 Summary of damage

A summary of damage to structures is found in table 5-1, and table 5-2, contains a summary of damage to equipment.

After the fallout danger, if any, has passed, the first tasks of the technical personnel will be assessment of damage and evaluation of the capabilities of the surviving equipment and systems. Priorities can then be established for repair, and the proposed degree of recovery - whether complete or partial - can be determined.

An initial rough estimate of the nature and extent of the damage will determine repair methods, equipment, material, and the personnel required for a partial recovery in order to initiate emergency operations.

5.4.2 Spare parts and cannibalization

The plant is not heavily stocked with spare parts. A nominal supply of parts is kept on hand to take care of normal wear on processing machines and canning equipment, but additional parts and equipment would have to be acquired from outside sources under extreme damage conditions.

Possibilities for cannibalization of equipment within the plant are limited. The only processing machines which can be cannibalized to restore a surviving unit are the juice extractors and the canning machines. Conveyor parts from the receiving system and pulp-handling equipment might be used to repair surviving conveyor equipment in the main processing system within the plant. All other equipment would have to be acquired by mutual exchange with other plants, of which there are many in the central Florida area (see figure 5-2).

A final assessment can be made later to determine the effort required for the complete recovery of the plant.

5.4.3 Initiating emergency operation

After the period of damage assessment, the minimum requirements for the resumption of operations under emergency conditions can be established.

The minimum requirements for each of the three blast damage ranges are as follows:

Operation following low blast damage (0.0 psi to 0.5 psi)

The functions of the dry goods warehouses and cold storage houses are of secondary importance in restoring the plant for emergency operations, since the juice could be hotpacked as single strength or as concentrate, thus obviating the need for refrigeration. All processing equipment will have to be checked and cleaned of dust, debris, and material which may have decayed during the fallout period, if any. Gauges, instruments, small piping and sheet metal equipment will have to be repaired or replaced before production can start.

Table 5-1 Summary of Damage

Pressure (psi)	Receiving and Pulp-Handling Equipment	Process Building Low Bay 1	Process Building High Bay 1	Bin Building 4	Juicer Building 5	Dry Goods Warehse. 6	Cold Storage House 8	Cold Storage House 10
0.1		Glass Cracking	Glass Cracking		Glass Cracking			
0.5		Glazing Shattered	Corrugated Asbestos Siding Fails Glazing Shattered		Glazing Shattered	Conc. Block Walls Fail	Conc. Block Walls Fail	Conc. Block Walls Fail
1.0						St. Frame Failure		St. Frame Failure
1.5					Corrugated Asbestos Roof Failure			
2.0		Roof & Walls Collapse						
3.0	General Failure of Towers-Conveyors-Sorting Stands etc.							
4.0		Frame Failure	Frame Supporting 5 Evaporators May Collapse					
5.0	Frame Failure				Frame Failure			
6.0								
7.0			Moderate Distortion of Equip. Support Towers Integral with bldg. frame	(Empty) Cols. Fail				
10.0			Collapse and Severe Equipment Damage					

…ry of Damage to Structures

…d …rage …ise …0	Cold Storage 13	Cold Storage 14	Bin Building 15	Dry Goods Warehse. 16	Maintenance Building 17	Dry Goods Warehse. 24	Dry Goods Warehse. 25	Pump & Boiler House	Steel Stack
					Glass Cracking			Glass Cracking	
…c. Block …ls Fail		Conc. Block Walls Fail		Conc. Block Walls Fail	Glazing Shattered	Corrug. Metal Siding Fails	Conc. Block Walls Fail	Siding Destroyed Glazing Shattered	
…Frame …lure	Conc. Frame Fails	St. Frame Failure			Corrugated Asbestos Roof Failure		St. Frame Failure		
				St. Frame Failure					
	Conc. Block Walls Fail								
					Frame Failure	Rigid Frame Failure			Overturns
								Frame Collapse	
			(Empty) Cols. Fail						

Table 5-2 Summary of Damage to Processing Equipment

Structural	Critical Overpressure	Processing Equipment
Missile damage in Process Bldg.	0.5	Damage to gauges & small piping.
Walls fail at all warehouses & cold storage hses. #8, 10, 14		Material spilled from broken bags & cans.
Frames fail at drygoods whses #6 & 25 and cold storage hses. #10 & 14	1.0	Material spilled from bags and cans. Refrig. equip. damaged in cold storage hses.
Corrug. asbestos roof fails in Juicer Bldg.	1.5	Slight damage to equipment.
Walls fail at cold storage house #13	2.0	Material spilled from cans.
Steel frames fail at drygoods warehouse #16		Material spilled from broken containers.
Roof & walls collapse at Process Bldg. (low bay)		Conveyors, refrig. equip., can sealers, packaging equip. damaged.
Water Tower (empty) fails	3.0	Piping and connections at tower severely damaged.
Molasses Evap. Tower fails		Evaporator and piping damaged.
	4.0	Receiving equip. such as conveyors and sorting machines damaged.
Frame fails at Process Bldg. (low bay)		Increased damage to conveyors, refrig. equip., can sealers & packaging equipment.
Evap. frame in Process Bldg. (high bay) fails		Slight damage to evaporators and piping.
Receiving & Pulp Handling Towers fail	5.0	Conveyors & sorting equip. demolished.
Frame fails at Juicer Bldg.		Slight damage to juicing machines.

Structural	Critical Overpressure	Processing Equipment
Frame fails at Maintenance Building		Machine shop equipment damaged.
Stack overturns		Connections to boiler house damaged.
Water Tower (full) topples		Tower & piping suffers severe damage.
Boiler house frame fails	6.0	Damage to boilers & allied equipment.
Evaporator support frame in Process Bldg. (high bay) shows distortion	7.0	Piping connections damaged. Slight missile damage to evaporators.
Frame of Process Bldg. (high bay) and the independent frame supporting evaporators fail	10.0	All equipment in bldg. suffers severe damage and in the case of concentrators & evaporators they are destroyed.

Operation following medium blast damage (0.5 psi to 5.0 psi)

To protect the equipment from further damage due to inclement weather, the collapsed roof and walls of the process building (low bay) must be restored and all equipment such as conveyors, can sealers, and packaging units required for the processing of the simplest form of packaged juice (hotpack) should be repaired. The quick-freeze refrigeration room need not be rebuilt at this time, because it is not required in the production of hotpacks.

The general damage to the receiving equipment and its structural supports should be checked and repaired to facilitate the conveying of fruit from the trucks to the processing system.

The five high-temperature evaporators supported by the independent frame in the high bay of the process building should be checked and repaired and their supporting frame either repaired or a temporary supporting system installed. The repair work to these evaporators as well as the process system, before and after the introduction of juice to them, must be given the highest priority in order to produce the concentrated hotpack. The damage done to this hotpack system is repairable for emergency operation within this range.

The juice extractors must be checked and cleaned of all debris and dirt incurred by the failure of the corrugated asbestos roof.

Operation following high blast damage (5.0 psi to 10.0 psi)

In addition to rebuilding the receiving towers and their conveying equipment, the frame of the juicer building should be rebuilt as well as the stairs and platforms leading to the juice extractors.

The overturned stack will have to be rebuilt because of its proximity to the process building. If the stack were not rebuilt, as has proved possible in the cases of some other plants which also have forced draft fans, the smoke would enter the process building at poorly lapped joints of the corrugated metal siding as well as through makeshift temporary siding, with consequent damage to juice in process.

The frame, which is integral with the building frame of the process building (high bay) and which supports a number of evaporators, will suffer only moderate distortion; therefore, the evaporators themselves will probably suffer nothing more tham missile damage. The frame could be straightened and the piping checked and repaired. Any level of overpressure beyond this range would leave the distribution of whole fruit as one alternative, or undamaged fresh fruit on hand could be transferred to another, undamaged plant.

At the upper level of this blast damage range, the frame of process building (high bay) will collapse, bringing down both the roof and a traveling crane. The minimum requirement in this case would be the complete rebuilding of the process building because of the amount of damage incurred.

5.4.4 Shortcuts

Under emergency conditions, all products and byproducts except the hotpack concentrate could be discontinued. The production of this hotpack concentrate is readily made because it is a product which is normally shipped to institutions and the military. This particular plant produced approximately 1.2 million gallons of this product per year. Although it has a "canned" flavor and there is some loss of vitamin content, it does not require refrigeration.

5.4.5 Utilities

Water supply

The water mains are underground and are not considered vulnerable within the range of overpressures for which the plant was analyzed.

Electric power

Electric power is very important at this plant and can be cut off by missile damage to the circuit breaker panel in the boilerhouse at the low overpressure of 0.5 psi. A longer delay in the supply of electric power will occur at overpressures greater than 4.0 psi, when the transmission poles are blown down.

Gas supply

The gas mains which supply fuel to the boilers are underground and are not vulnerable, but the connection within the boilerhouse of the gas main to the boiler is vulnerable to missiles. A break in this line from missiles may cause an explosion which could compound the damage to the boilerhouse and other buildings in close proximity.

5.4.6 Repair required to resume normal operation

Low blast pressure range

Although considerable damage is done to the warehouses, cold storage houses and their contents at these very low overpressures, complete recovery can be accomplished with 1560 man-days over a 20-day period.

Concrete block walls would be rebuilt at cold storage houses No. 8, 10 and 14 and at all dry goods warehouses except warehouse No. 24, where corrugated metal siding would have to be replaced.

A careful inspection of whole fruit, juice and processing equipment will have to be made before and after cleanup, to assess needed repairs and evaluate contamination from fallout.

Medium blast damage range

To the repair accomplished in the low blast damage range, the following repair must be added.

As a result of the wall and frame failures between 1.0 and 3.0 psi of the drygoods warehouses and the cold storage houses, considerable cleaning up of debris and spilled material from torn feed bags and broken cans of juice would be required, after which the cans which were still intact could be washed and restacked. Spilled feed, from broken bags, could be piled up and shoveled into empty, undamaged bags. There would be a point, of course, where spoilage by dirt, dust, and other debris would render the feed unfit for animal consumption, and if there were radioactive contamination, the feed would have to remain untouched until radioactivity had fallen to such levels as would be safe, both for handling by humans and consumption by cattle. Broken glass would not be a problem, since the warehouses have no windows. Much will depend upon the roof remaining relatively intact, and upon the weather, since heavy rains would render much of the feed unusable in a very short time. The steel frames of dry goods warehouses No. 6, 16 and 25, cold storage houses No. 10 and 14 as well as the concrete frame of cold storage house No. 13, will require rebuilding. As a result of the collapse of the walls and roof at the process building (low bay), a great deal of repair work would be required on comparatively intricate equipment such as can sealers, packaging equipment and refrigeration units. The walls and roof of this processing building could be rebuilt simultaneously with the repair of the equipment.

At the 3.0 psi level of damage, the water tower, if empty at the time of the blast, will require rebuilding and repiping with new components, exclusive of any equipment which is deemed salvageable after inspection. The failure of the molasses evaporator tower, if full at the time of failure, would create very messy cleanup work. The conveying and sorting equipment will require careful checking, repairing or replacing parts and alignment by an engineer.

At 4.0 psi, the receiving and pulp handling equipment will require repairing or replacing parts. The frame of the process building (low bay) will have to be rebuilt as well as the independent frame supporting the five evaporators in the process building (high bay). The evaporators supported by this independent frame are rugged and will probably only require checking and minor repairs. All other evaporators and concentrators would require checking and repairing for damage from missile effects.

High blast damage range

At 5.0 psi, the receiving and pulp handling towers will require complete rebuilding, as will the conveying and sorting equipment. The steel frame of the juicer building needs replacing and the stairways and platforms at the juicing machines will require repair of extensive damage. The juicing machines are of rugged construction and there are enough of them so that a juicing operation could be started through cannibalization and repair of the salvageable units. The rigid frame, girts and purlins at drygoods warehouse No. 24 will require replacing. The frame of the maintenance building needs rebuilding and replacement parts for the machine shop equipment would have to be obtained in order to use these machines in the repair of plant equipment. The overturned stack must be rebuilt as well as its connections to the boilerhouse. The entire reconstruction of the water tower is required, even if the tank is full at the time of the blast.

At 6.0 psi, boilers and their attendant equipment will need repairing, and at 7.0 psi, the equipment support frames which are integral with the frame of the process building (high bay) will require straightening and realignment. The piping connected to concentrators and evaporators support columns of the bin buildings No. 4 and 15 will be required, if they are empty at the time of the blast. No repair is required if the bins are full.

A total of 30,480 man-days will be required to repair the damage incurred up to 10 psi. At 10 psi and above, it would be uneconomical to attempt any repair.

5.4.7 Substitutes

Whole (fresh) fruit could, of course, be distributed to disaster areas until such time as the demand for processed juice could be filled.

5.4.8 Increased production capability

During the orange picking season, the plant works on an around-the-clock basis, and it can handle all the fresh fruit delivered. Normally, an increase in production is entirely dependent upon the crop yield. In a postattack emergency, production could be increased considerably provided the fresh fruit were available for processing. It might prove possible to operate the plant during the six months when it is ordinarily "down", either by importing fruit from abroad or by stocking refrigerated warehouses during the picking season with excess whole fruit at low, but above freezing temperatures. The stored excess fruit would be processed at the end of the picking season, when supplies direct from the groves begin to dwindle. It could prove advantageous for the plant to switch production entirely to hotpack concentrate, even if the frozen concentrate capability remained, in order to make refrigerated storage space available for the excess whole fruit rather than for processed frozen concentrate.

5.4.9 Estimated man-days required for repair for each level of blast pressure

These estimates will be found on the following charts. Figure 5-7, the Recovery Chart following these charts illustrates graphically the repair effort in man-days to initiate emergency operation and for complete recovery to resume normal operations.

ORANGE JUICE PROCESSING PLANT

Low Blast Damage Range 0 to 0.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
0.1	all glass cracks dust & fallout	clean up dust	laborers	12	10	120
0.5	glass shattered (all windows)	replace glass	carpenters	15	20	300
	Corr. metal siding fails at process bldg., boilerhouse, & warehouse #24	replace siding	iron workers laborers	10	14	140
	conc. block walls fall at all warehouse and cold storage houses #8, 10 & 14	rebuild walls	masons laborers hoisting eng.	30	20	600
			Structural			1160
	PROCESS					
0.1	dust & fallout					
0.5	broken glass & missile damage in process bldg.	clean equip. repair damage to gauges & small piping	mechanics laborers	10	10	100
	conc. block walls fail @ all warehses. & cold storage hses. #8, 10 & 14	clean up debris spilled material from broken bags and cans. Sort and re-stack cans & bags	laborers	30	10	300
			Process			400
			Structural			1160
		Total Man-Days for Low Range				1560

ORANGE JUICE PROCESSING PLANT

Low Blast Damage Range 0 to 0.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
	Clean up dust & glass shards			12	10	120
	Process					
	Clean equipment, repair damage to gauges & small piping in Process Building			10	10	100
		Total Man-Days for Low Range				220

ORANGE JUICE PROCESSING PLANT

Medium Blast Damage Range 0.5 to 5.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
1.0	steel frames fail at dry goods warehses. #6 & 25 and cold storage warehses. #10 & 14	repair frames	ironworker crane opr. laborers foremen	30	30	900
	conc. frame fails at cold storage warehse. #13	repair frame	carpenters rod busters laborers foreman	25	30	750
	corrug. asbestos roof fails at maintenance bldg.	repair roof	ironworkers helpers	8	5	40
1.5	corrug. asbestos roof fails at juice bldg.	repair roof	ironworkers helpers	8	5	40
2.0	conc. block walls fail at cold storage warehse. #13	rebuild walls	masons laborers crane opr.	20	10	200
	steel frame fails at dry goods whse. #16	repair frame		8	30	240
	roof & walls collapse at process bldg. (Low Bay)	repair roof, walls & refrig. room	ironworkers carpenters laborers crane opr.	25	60	1500
3.0	water tower (empty) fails	rebuild tower	ironworkers laborers crane opr.	10	30	300
	molasses evap. tower fails	rebuild tower	ironworkers laborers crane opr.	5	10	50
4.0	general damage to receiving & pulp handling equipment	check steel towers	ironworkers laborers crane opr.	10	30	300
	steel frame fails @ process bldg. (Low Bay)	rebuild frame	ironworkers laborers crane opr.	30	30	900
4.0	interior steel frame supporting 5 evaps. in process bldg. may collapse (high bay)	rebuild frame	ironworkers laborers crane opr.	10	20	200
			Structural			5420

ORANGE JUICE PROCESSING PLANT

Medium Blast Damage Range 0.5 to 5.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS					
1.0	steel frames fail at dry goods warehses. #6 & 25 and cold storage warehses. #10 & 14	clean up material from broken bags & cans. Sort & restack bags & cans.	laborers	20	10	200
		Repair refrig. equip. in cold storage whses.	engineer tradesmen	20	60	1200
1.5	corrug. asbestos roof fails in juicer bldg.	clean up and overhaul equip.	engineer tradesmen	10	60	600
2.0	conc. block walls fail in cold storage warehse. #13	clean up debris sort & restack cans	laborers	5	20	100
	steel frames fail @ dry good warehse. #16	clean up material from broken containers. Sort & restack material	laborers	5	20	100
	roof & walls collapse @ process bldg. (low bay)	repair conveyors, refrig. equip., can sealers, packaging equip. sort & restack empty cans	engineer technicians tradesmen laborers	20	90	1800
3.0	water tower fails (empty)	repair piping & connections	technicians laborers	5	60	300
	molasses evap. tower fails	repair evap. & piping	technicians laborers	10	30	300
4.0	receiving equip. damaged	repair conveyors, sorting equip. etc.	engineers tradesmen	10	60	600
	process bldg. frame fails (low bay)	repair & replace conveyors refrig. equip., can sealers, packaging equip	engineers technicians tradesmen (in addition to roof & wall failing)	10	60	600
	Evap. frame in process bldg. fails (high bay)	repair evaporators	engineers tradesmen	20	30	600
			Process			6,400
			Structural			5,420
		Total for 0.5 psi to 5.0 psi				11,820
		Total for Low Range				1,560
		Total Man-Days for Medium Range				13,380

ORANGE JUICE PROCESSING PLANT

Medium Blast Damage Range 0.5 to 5.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
1.5	Repair roof of Juicer Bldg.			8	5	40
2.0	Repair roof, walls & refrigeration room of Process Bldg. (Low Bay)			25	60	1500
4.0	Check steel towers of receiving & pulp handling equipment			10	30	300
	Rebuild steel frame of Process Bldg. (Low Bay)			30	30	900
	Rebuild interior steel frame supporting 5 evaporators in Process Bldg. (Low Bay)			10	20	200
	Process					
1.5	Clean up & overhaul equipment in Juicer Bldg.			10	60	600
2.0	Repair conveyors, refrig. equip., can sealers packaging equip. in Process Bldg. (Low Bay)			20	90	1800
4.0	Repair conveyors, sorting equip., etc. of receiving equipment			10	60	600
	Repair & replace conveyors, refrig. equip., can sealers, packaging equip. of Process Bldg. (Low Bay)			10	60	600
	Repair evaporators in Process Bldg. (High Bay)			20	30	600
		Total for 0.5 to 5.0 psi				7140
		Total for Low Range				220
		Total Man-Days for Medium Range				7360

ORANGE JUICE PROCESSING PLANT

High Blast Damage Range 5.0 to 10.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
5.0	receiving & pulp handling towers fail	rebuild towers (in addition to med. blast damage)	ironworkers laborers crane opr.	10	30	300
	frame fails at juicer bldg.	rebuild frame, stairways & platforms	ironworkers laborers crane opr.	20	60	1200
	rigid frame fails at warehouse #24	rebuild	ironworkers laborers crane opr.	20	60	1200
	frame fails at maintenance bldg.	rebuild	ironworkers laborers crane opr.	30	30	900
	stack overturns	rebuild	ironworkers laborers crane opr.	20	30	600
	water tower (full) topples	rebuild (in addition to med blast damage)	ironworkers laborers crane opr.	10	30	300
6.0	frame at pump & boilerhouse fails	rebuild	ironworkers laborers crane opr.	20	30	600
7.0	equip. support frames integral with bldg. frame suffer moderate distortion at process bldg. (High Bay)	check and repair frames	ironworkers laborers crane opr.	20	30	600
	columns fail @ bin bldgs. #4 & 15 (bins empty)	jack up & re-mount bins on new pedestals	carpenters laborers crane opr.	30	60	1800
			Structural			7,500
	Note: At 10 psi or above it is no longer economical to repair the plant					
10.0	process bldg. collapses (High Bay)	rebuild				

ORANGE JUICE PROCESSING PLANT

High Blast Damage Range 5.0 to 10.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS					
5.0	receiving & pulp handling towers fail	rebuild conveyors, sorting equip., etc.	engineer technicians laborers	20	60	1200
	frame fails at juicer bldg.	repair & replace juicing equip.	engineer technicians laborers	20	90	1800
	frame fails at maintenance bldg.	repair equip.	mechanics helpers	30	30	900
	stack overturns	rebuild connection to boiler house	technician helpers	10	60	600
	water tower (full) topples	(damage the same as that of failure when empty)	technicians laborers	--	--	--
6.0	boilerhouse frame fails	repair & replace equip.	engineer technicians helpers	20	90	1800
7.0	equip. in feed mill area severely damaged	repair & replace equip.	engineer technicians helpers	30	90	2700
	equip. support frame distortion @ process bldg. (High Bay)	check equip. & repair piping connections	technicians helpers	20	30	600
			Process			9,600
			Structural			7,500
		Total for 5.0 psi to 10 psi				17,100
		Total for Medium Range				13,380
		Total Man-Days for High Range				30,480
10.0	process bldg. collapses (High Bay)					

ORANGE JUICE PROCESSING PLANT

High Blast Damage Range 5.0 to 10.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair Men	Repair Days	Repair Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
5.0	Rebuild towers of receiving & pulp handling towers			10	30	300
	Rebuild frame, stairways & platforms of Juicer Bldg.			20	60	1200
7.0	Rebuild overturned stack			20	30	600
	Check & repair equipment support frames which are integral with building frame of Process Bldg. (High Bay)			20	30	600
	Process					
5.0	Rebuild conveyors, sorting equip., etc. of receiving & pulp handling equipment			20	60	1200
	Repair & replace juicing equip. in Juicer Bldg.			20	90	1800
	Rebuild stack connection to Boilerhouse			10	60	600
6.0	Repair & replace equip. in Boilerhouse			20	90	1800
7.0	Check equip. & repair piping connections to equip. supported by frames which are integral with building frame of Process Bldg. (High Bay)			20	30	600
		Total for 5.0 psi to 10 psi				8,700
		Total for Medium Range				7,360
		Total Man-Days for High Range				16,060

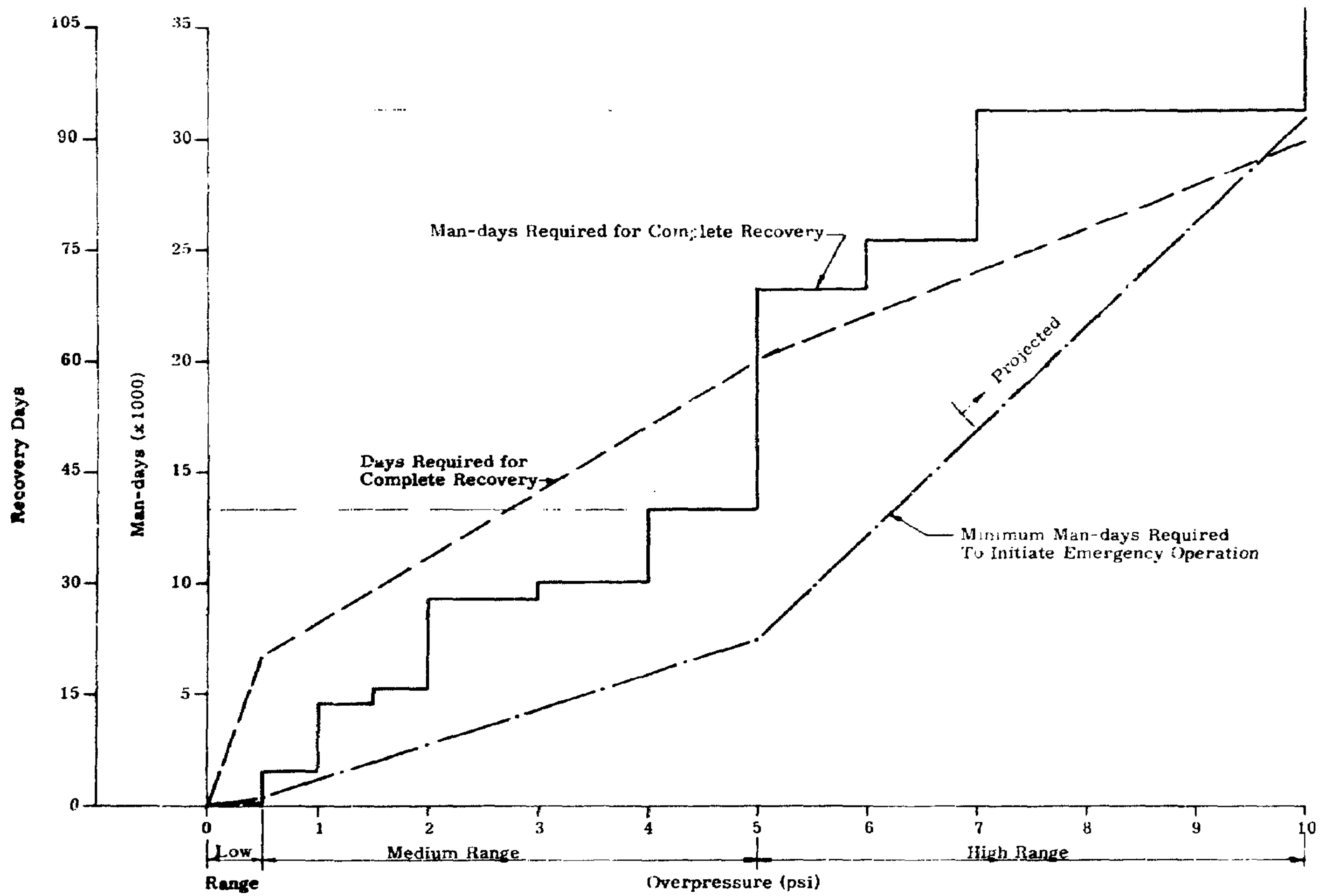


Figure 5-7 Recovery Chart - Citrus Juice Processing Plant

5.5 CONCLUSIONS

The orange juice industry is considerably more localized than other industries. Three quarters of all the United States' orange juice is produced in one narrow belt of Florida; this geographical concentration makes the industry highly vulnerable.

Depending on the condition of the processing plant after a nuclear attack. the refrigeration requirement could be completely eliminated by the production of hotpack juice (concentrated or single strength), and in the event of near-complete destruction, fresh (whole) fruit could be distributed. All distribution would, of course, depend on the availability of transportation which should be analyzed as a separate study for the entire food industry.

Since there is a six months picking season, there is always some frozen concentrate in storage, which is shipped to markets to meet demand. Theoretically, there should be a six months supply on hand about June 1, the end of the picking and processing season, and very little on hand when the season begins again on December 1. Thus, the timing of an attack could have a great deal to do with the amount of damage done. For example, an early June blast with a relatively low overpressure of, say 0.5 psi, would not do a great deal of damage to the processing plant but could ruin the plant's peak supply of frozen concentrate if the warehouse were not immediately repaired, or if the contents could not be transferred elsewhere. Conversely, a December 1 blast of similar intensity would destroy an almost empty warehouse at a time when there would be little or no processing as yet, and thus might cause little discommodity to production at the plant, even if fall-out were to force employees to abandon work and go into shelters for two weeks or more.

If there is an adequate supply of fruit, production at the plant can be increased considerably. Excess fruit could be stored in the refrigerated warehouses, to be processed during the ordinarily slack summer months, although this could necessitate switching to hotpack production (section 5.4.8). However, if there is an orange freeze or other damage to trees, the production rate of an emergency product such as the hotpack or fresh fruit would certainly be curtailed.

Although there are many alternative sources of vitamin C, the orange juice industry represents a large, important, and relatively vulnerable component of the food industry. In the unlikely absence of all other sources of vitamin C, the normal Florida frozen concentrate production could provide minimum postattack long-term vitamin C requirements for over 75 million people. The four month time for a deficiency to develop is well within the repair cycles studied.[27]

Among the first facilities to be repaired would be the maintenance shop, because the machine tools will be invaluable in the repair of the plant.

6. FOOD CONTAINER INDUSTRY

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6. FOOD CONTAINER INDUSTRY

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6. FOOD CONTAINER INDUSTRY

6.1 A REVIEW OF THE INDUSTRY

6.1.1 General

The food is dependent upon adequate supplies of packaging materials for the preservation and distribution of its products. The forms these packages take reflect the processing, distribution and consumption patterns of foodstuffs, and provide the means for breakdown of the products into conveniently storable, transportable, sellable and usable quantities.

A typical supermarket in the U.S. has over 8,000 items, of which 85% are packaged in some way.[28] This percentage has been increasing in recent years. Although some of this packaging is principally for convenience and "buy-appeal", much of it is essential for cleanliness and preservation.

6.1.2 Types of containers

The principal food packaging media are 1) metal cans 2) glass jars & bottles 3) paper & paperboard containers, and 4) flexible barrier materials made of plastic or cellulosic films, aluminum foil, or combinations of these with each other or with paper.

Because of the widely varying types, sizes and shapes of food containers, detailed statistics do not exist on actual usage of all of the several types. However, production data do exist which can shed light on their relative importance.

Cans

Tin plate produced for metal cans in 1963 amounted to 4.66 million short tons.[28] Aluminum accounted for about 43,321 additional tons. This equates to unit production of above 33 billion cans. Of this production, 53.9% was used for food cans, 25.8% for beverages, 4.2% for pet foods, 2.3% for pressurized aerosol cans, and 13.8% for non-food use. In the latter category, motor oil and paints account for a large proportion. Thus, a total of 83.9% (first 3 categories) could, in an emergency, be made available for preservation of food and drink, and probably some portion of the last category.

Glass containers

Forty-one manufacturers with 105 plants produced 25.5 billion units of all types in 1963. Food uses consumed approximately 2.7 billion narrow-neck bottles, and approximately 8.7 billion wide-neck jars.[28] Comparison of this last figure with the roughly 17.8 billion cans used for food indicates their relative popularity.

Americans used about 200 food and beverage cans and glass jars per capita in 1963.

More beverages are packed in cans than bottles: 8.5 billion cans vs. about 6.5 billion bottles in 1963. Beverage can use has increased five fold since 1958. Total bottle production for all uses was over 25.6 billion.

It is important to note that a glass container plant can quickly shift production from one type of container to another, such as from narrow-neck bottles to wide-mouth jars, simply by changing molds on their glass-blowing machines. Most plants have a wide variety of such molds, shifting production to meet demand. Hence, production in a postattack situation could be relatively easily shaped to emergency needs. Such product shifts are less easily accomplished at a metal can plant.

Paper and paperboard containers

Unit production in these categories is more difficult to estimate because of the wide variety of sizes and shapes of containers made, and the use of "foodboard" in combination with flexible barrier materials. Of the over 8000 items in the typical U.S. supermarket, however, the majority are paper-packaged. The use of paper to package foods, nonetheless, may generally be taken as an indication that preservation requirements for those foods are not stringent as they are for those packed in air-tight containers. In a postattack environment, packaging standards could be lowered, with many dry foods distributed in bulk, using a "cracker-barrel" approach.

1963 production of sanitary foodboard was 1,750,000 short tons (18.9 lbs/capita); of folding box board, 3,150,000 tons (34.1 lbs/capita); of glassine and vegetable parchment, 190,000 short tons (2.0 lbs/capita). Sanitary foodboard is generally used for paper packages directly contacting the food, such as frozen vegetables, whereas many food cartons, such as for cereal, are made of boxboard with a glassine liner.

There are 459 companies operating 612 plants producing folding cartons in the United States. Production is well dispersed, with little geographical or corporate concentration.

Flexible barrier materials

These are so diverse in their food packaging usage as to defy meaningful numbers. However, the use of film, foil and combinations in the field has grown dramatically in the last decade.

This report has chosen for study one high-volume use of such a combination package, the milk carton. Although the plant studied produces waxed paperboard milk cartons of quart size and smaller, the same company makes its larger 1/2 gallon and gallon containers of 2-side polyethylene-coated board. The industry trend is toward the use of this latter material in all milk cartons.

Over 25 billion milk containers are manufactured each year, 70% of them of quart or larger size. The half-gallon size accounts for 1.2 billion gallons, the quart size, 8.9 billion gallons.[29]

6.1.3 Geographical locations

Figures 6-1 and 6-2 illustrate the fact that the metal can and glass containers manufacturing industry is widely dispersed. The rural character of most of these locations, away from metropolitan centers, would tend under most attack situations to preserve a very significant portion of the industry's productive capacity.

Figure 6-3, showing locations of coating and blanking plants for milk cartons, depicts a slightly different picture. Coating is generally done at the paper mills, which are usually located away from metropolitan centers. However, the carton plants tend to be in metropolitan areas near their customers, because of shipping economy. Substitute facilities for the carton-blanking operation are available in general-purpose printing plants on a widely scattered basis, in the event of destruction of a high proportion of the production capacity of the carton plants. Further, if the metropolitan dairy plants were destroyed, much capacity for processing and packaging milk exists in smaller rural plants. These plants now usually operate as collection centers for raw milk and ship in bulk tank cars or trucks to the city plants, while bottling some portion of their milk for local distribution. Since these facilities are now typically used on a less than full-shift basis, capacity exists there for expanded output.

6.1.4 Transportation

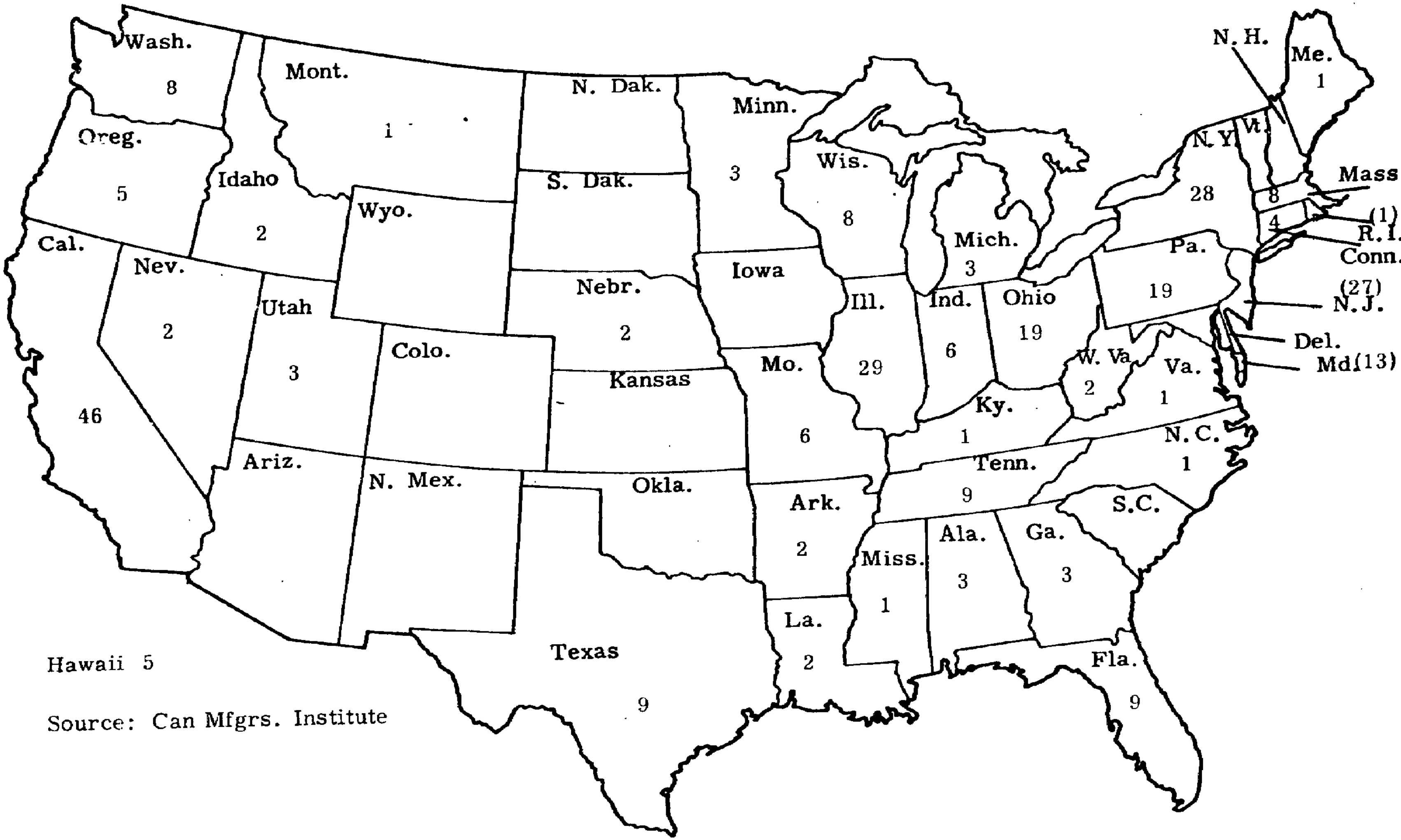
Transportation was not separately studied in regard to moving containers to food processing plants. However, the information developed on industry structure and geography permits some observations.

Plants making rigid containers are generally located in agricultural regions, as are canneries. Hence transportation hauls are short and will not cause undue difficulty in a postattack environment. In fact, some can-making plants are located adjacent to the processing canneries. Shipping tin plate from steel centers to can plants may well present a more complex problem, however.

Plants making flexible barrier packaging materials are well dispersed, but also tend to be located closer to their markets than their supply sources. For the types of foods typically packaged in these media, this tends to mean package plant locations in or near metropolitan centers. These plants may ship to customers anywhere, by all transport methods, but under emergency conditions much mutual accommodation by package manufacturers and food packers in a local area could be accomplished to reduce transport nationwide requirements.

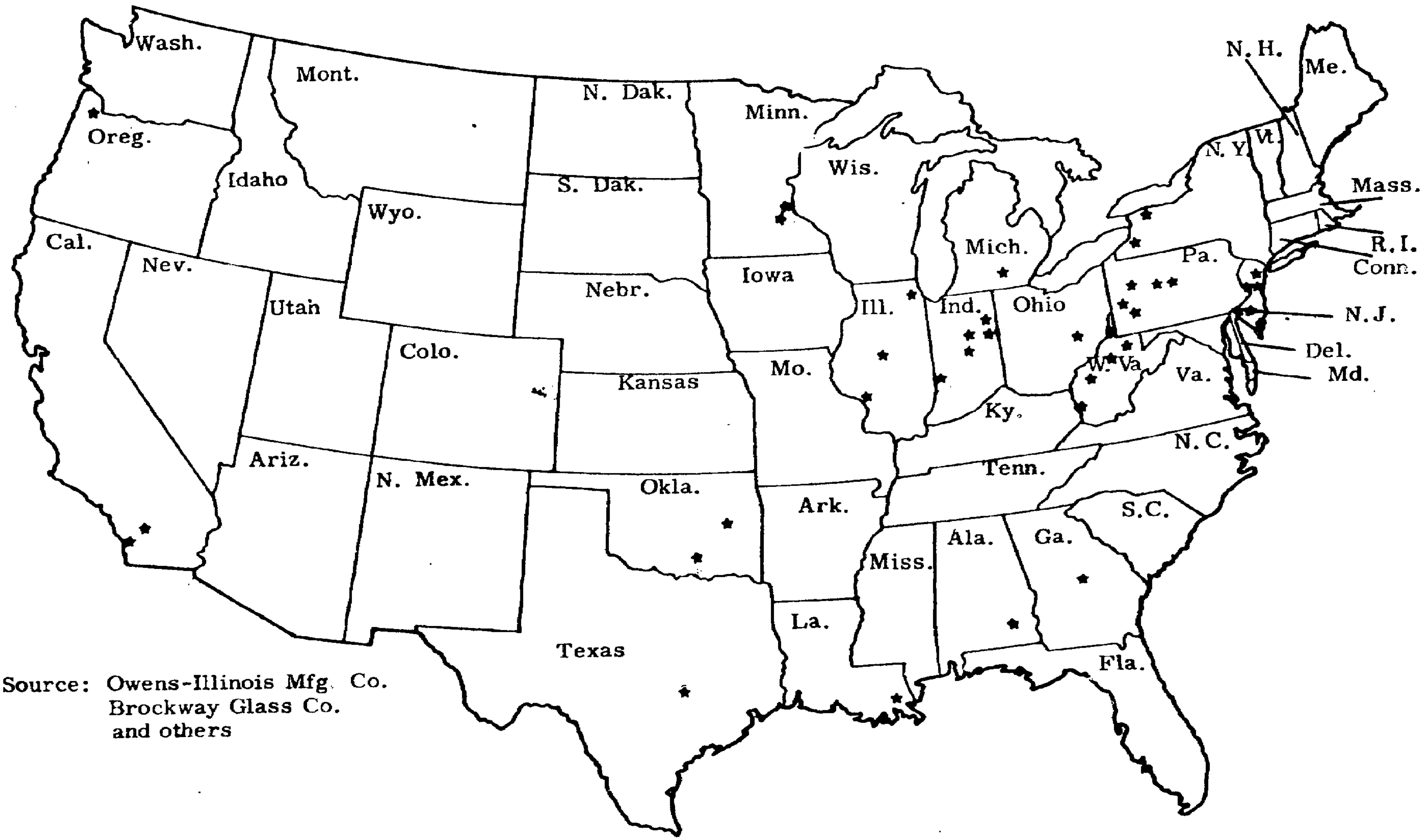
6.1.5 Trends

Packaging materials for food are intensively competitive, volume is high and most foods can use alternative types of packages. As a result, it is a constantly, rapidly shifting business. Some underlying trends appear to be significant, nonetheless.



Source: Can Mfgrs. Institute

Figure 6-1 Metal Can Manufacturing Plants, 1964



Source: Owens-Illinois Mfg. Co.
Brockway Glass Co.
and others

Figure 6-2 Glass Container Plants, 1964

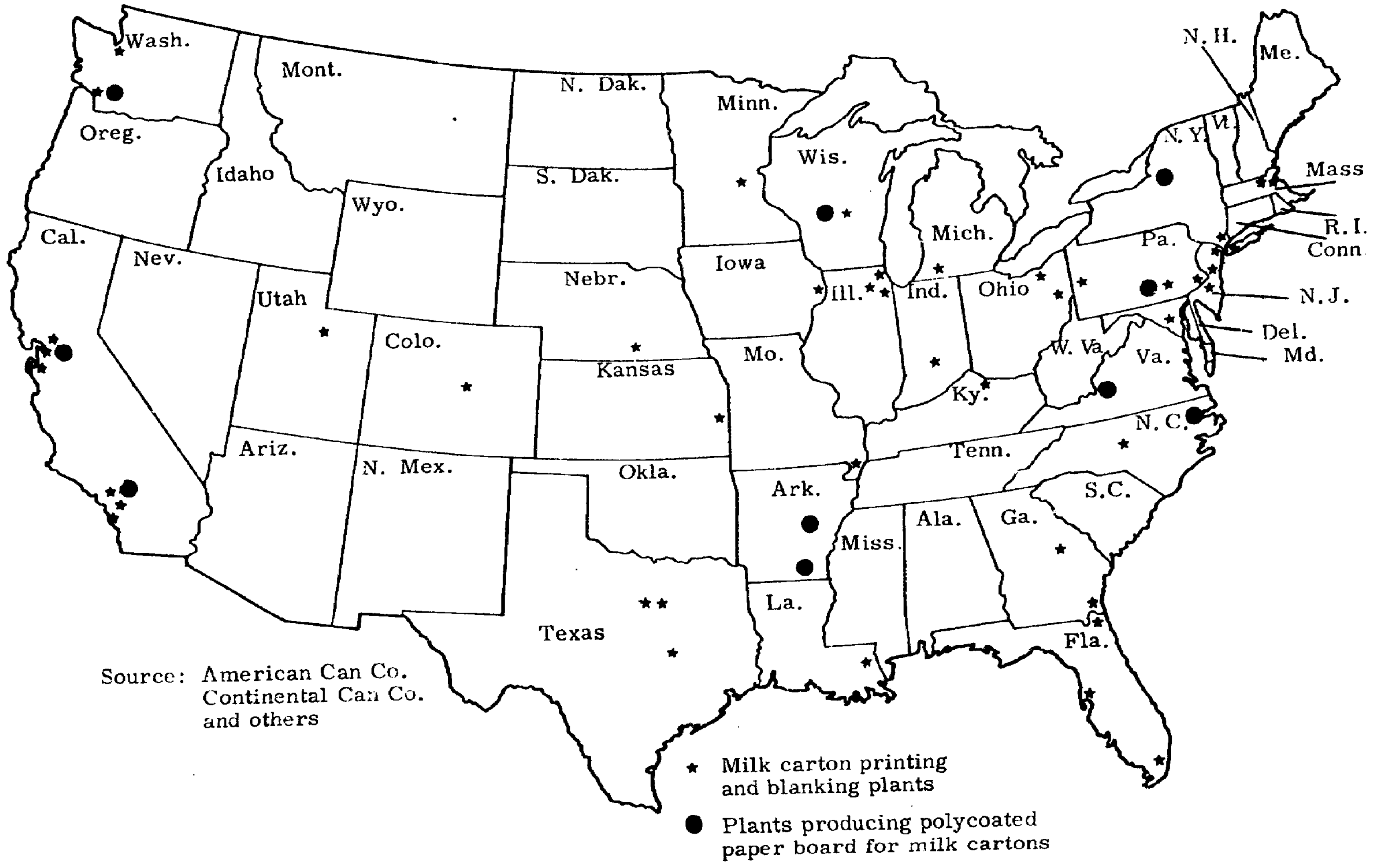


Figure 6-3 Paper Carton Manufacturing Plants, 1964

First is the growth of the total market as the proportion of processed and packaged foods increases.

Second is the supplanting of traditional materials by new ones, and proliferation of new materials and combinations. In the rigid container field, tin-plated cans are growing at the expense of glass jars and bottles (especially for beverages) aluminum and composite (aluminum foil and kraft paper) cans are making inroads on tin cans (especially for frozen jucies and non-foods), and blow-molded plastic containers are beginning to replace plastic-coated cartons.

Third, the new materials, especially plastic films, are facilitating the packaging of foods that have generally been previously sold unpackaged, such as fowl and fresh fruits and vegetables.

These trends are significant in that they indicate that, in a postattack environment, flexibility in substitution of materials will be both possible and advantageous.

6.2 METAL CAN PLANT

6.2.1 General Description

The American Can Company plant is located in the industrial area of Portland, Maine. The terrain is reasonably level and other buildings and plants surround the location. Railroad lines enter the grounds, and a paved street passes by, providing excellent shipping and receiving facilities.

The Portland plant consists of four principal buildings which include the manufacturing building, the warehouse, the service and general office building, and the boilerhouse, as shown in figure 6-4.

The steam boiler plant, office and manufacturing plant are each located in separate buildings. The office and plant are close enough to have an overhead passageway for easy access between the two. The three-story manufacturing building, 59 feet high by 242 feet x 187 feet in plan, was erected in 1919, and consists of a reinforced concrete frame and 12-inch brick walls with windows that generally comprise over 60% of the surface area. The roof and floors are reinforced concrete slabs on reinforced concrete beams.

The warehouse, built in 1940, is a single-story steel frame structure with 12" brick walls. There are about 17% openings all around except the west face, which is entirely glazed. The roof is made up to 2-inch wooden planks laid on steel purlins.

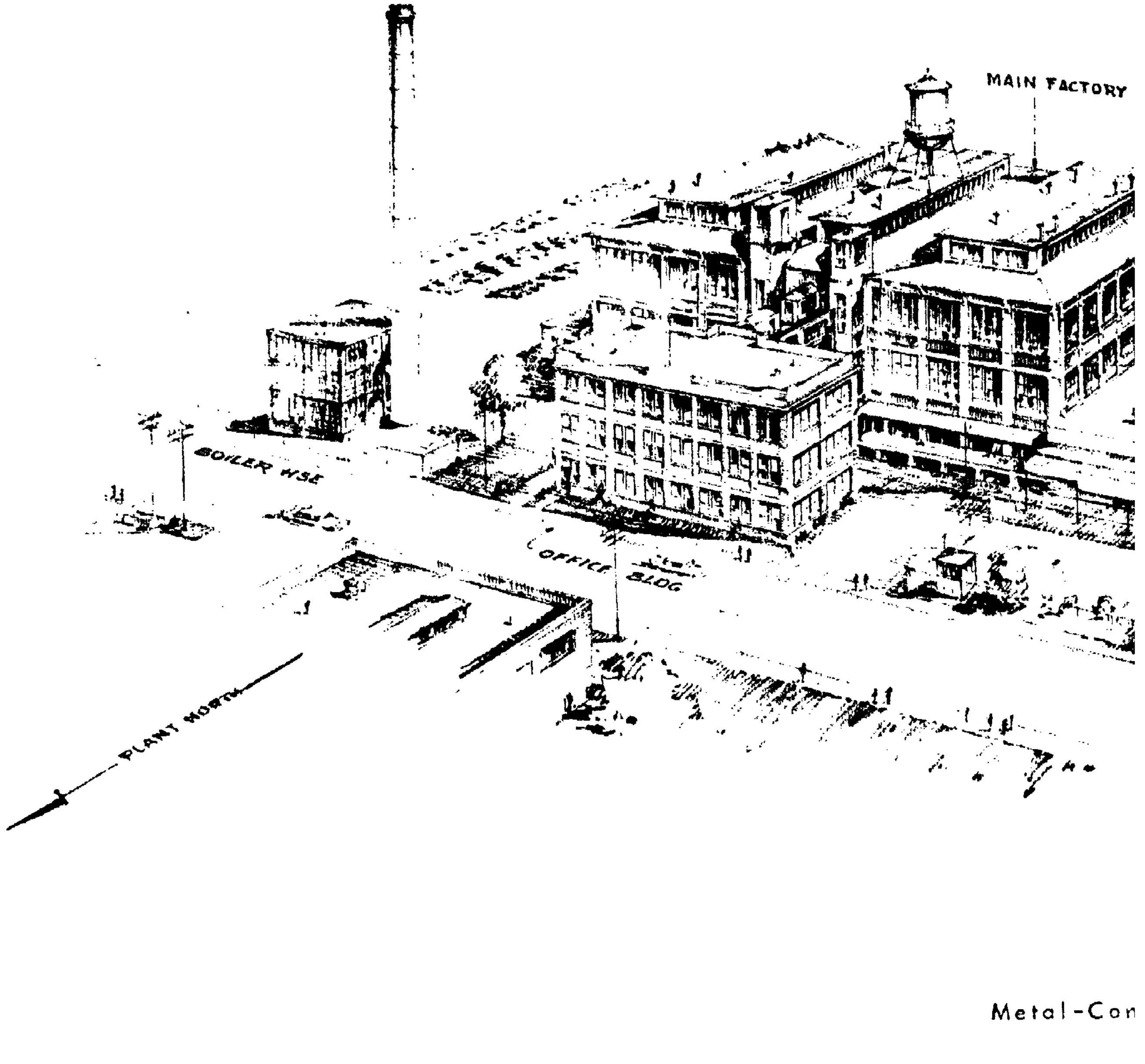
The office and service building (consisting of three stories) is approximately 114 feet by 46 feet by 59 feet high. It has a wooden frame and load bearing brick walls with more than 50% openings. The floors are generally concrete with composition covering, and the roof is constructed of wood, with tar and gravel topping.

The water tank for this plant has a rated capacity of 40,000 gallons and is supported by a four-legged tower about 34 ft. high and 22 ft. square at the base. This structure is mounted on top of the main building and extends above the roof.

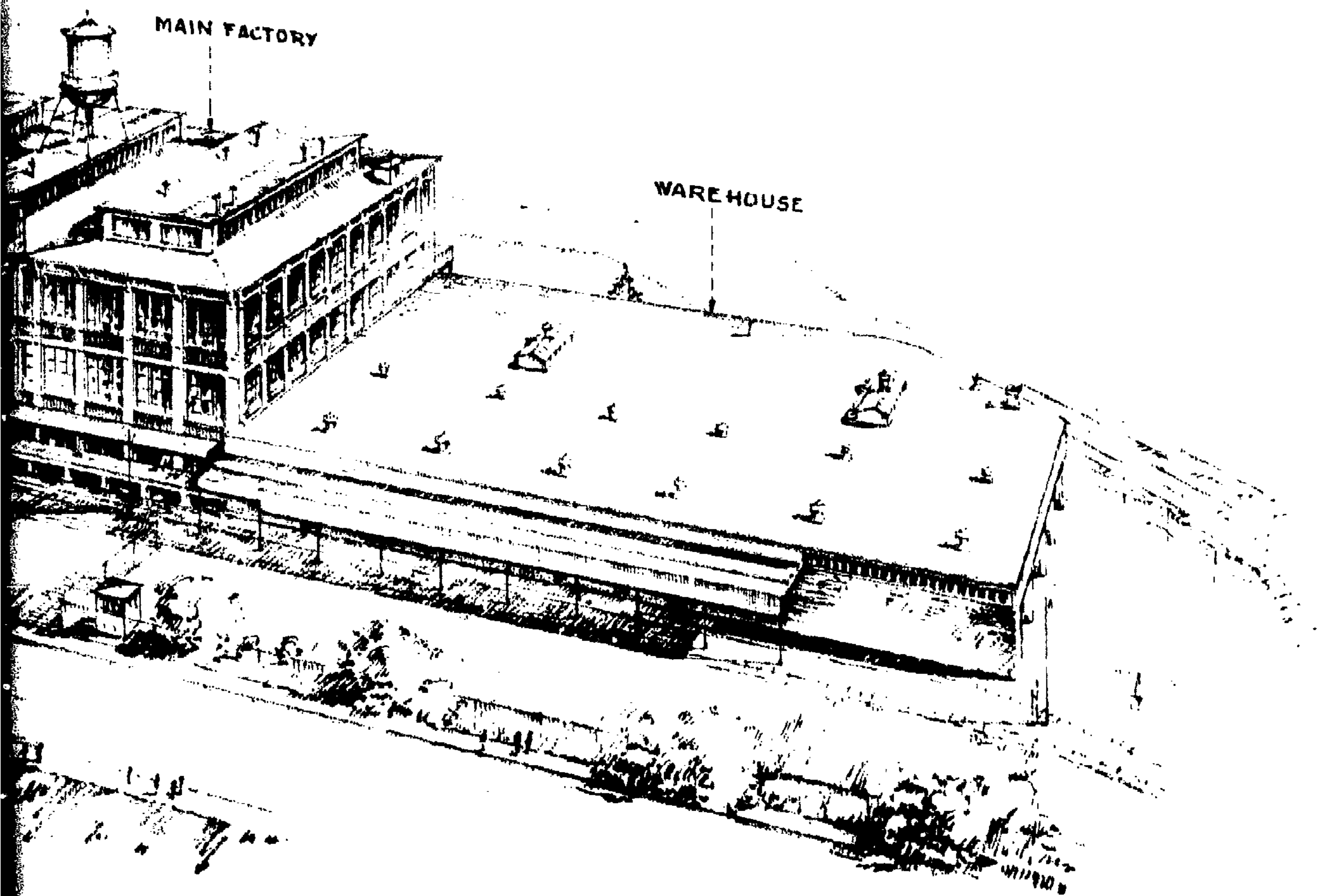
The boilerhouse was also built in 1940 and stands separate from all other buildings. It is approximately 43 feet square, 32 feet high, a single-story steel frame structure with brick walls up to 5 feet above the ground and glazed panels in steel sash for everything above. The roof is constructed or reinforced concrete slabs with tar and gravel topping. The glazed portion covers at least 80% of the wall area.

The brick stack associated with the boilerhouse is 125 feet high and has a base diameter of 10 feet.

The plant originally used three floors for production, but with modernization and new equipment, most of the work now is carried out on the third floor with some packaging on the second floor and all shipping and receiving done on the first or ground floor. The basement, under only a small portion at the rear of the plant, is used mainly for plant repair and service work.



Metal-Con



Metal-Container Plant

Figure 6-4

6.2.2 Operation

Tin-plated sheet steel is received either by truck or by railroad in bundles of one ton on each pallet. Forklift trucks are used to pick up the pallets, transfer them to the warehouse and stack them in large piles, which vary in height up to eight or ten feet, putting a considerable load on the floor. However, as this floor slab was placed on the ground, the loading does not effect the building.

When sheets are required for processing, the forklift truck again picks up the pallet of sheets, rides up the elevator to the third floor and deposits the pallet in the printing room. The bundles of sheets are placed on a machine which supplies one sheet at a time to a heavy-duty precision type roll-printing press unit. Four machines are used, each placing the varnish or print on the sheet accurately. For can bottoms and most covers (tops), varnish only is required, but some covers and most cans require printing as well. Varnish is placed on the inside face of all sheets for covers or can bodies, and printing material and varnish are placed on the outside face. Care is taken to leave the edges clean and free where soldering takes place.

Each sheet as it leaves the printing presses is placed on an endless chain and fed through a furnace for baking. The furnace is approximately 6 ft. in diameter and 90 ft. long. The temperature is maintained at 400°F as the sheets pass through in about 10 minutes, after which they are automatically removed from the chain and stacked on pallets. Periodically, a pallet load is picked up by a lift truck and moved to a metal shear machine, which cuts the sheets into strips or pieces of the size and shape to suit the lid or can being produced. These pieces are then placed in stacks and fed into the punch press, and forming machines.

The strips for covers and bottoms are fed into a punch press. This machine punches out the round ends and also presses the rings and grooves in them. The rings strengthen the ends and the groove is used for the sealing compound, a plastic rubber-like material which is placed in it. The ends are immediately passed in a continuous stream through a cooker-type unit heated with steam. When they emerge, the sealing material is well bonded to the metal groove. Half of these ends are used almost immediately on the bottoms of the cans; the remainder are packed and shipped to be used later as covers at the food processing plants, where they are placed and sealed by sealing machines.

Other sheets are cut to the size required for each can side and fed into the can body forming machine, in which 90 sheets are blanked one at a time, first being formed and then rolled to the curvature of the body. After being rolled, the bodies are moved along a form with the metal lap or joint of the can on the under side and the seam passes through a row of flames to heat it to the correct temperature for applying solder. Beyond the flame, the cans pass over tanks of hot solder with rollers turning to place solder along the full length of the seam. Immediately following this a brush wipes off the excess solder before it cools and sets. From here the can bodies are carried by a single file conveyor to a machine that forms a roll on each end to match the seal groove in the can ends. The body again moves on in a single file conveyor to another machine where it places one end on the can and seals it in place. From here the cans again move by conveyor to a test machine, where by means of air pressure, they are tested for leaks. Each can is picked up from the conveyor, placed with the open end against an air tube surrounded by a large washer, and held in a place under considerable force. Approximately 12 pounds of air pressure is applied to each can and if the pressure is maintained, the can is acceptable. If the pressure drops, the can is rejected. These rejects are then inspected by hand and checked for defects to determine if the manufacturing operations are satisfactory; if not, necessary corrections are made to prevent further rejects.

The accepted cans are then conveyed to the packaging area on the 2nd floor where they are palletized, wrapped in large bundles with heavy wrapping paper, and tied for shipping purposes. These large pallet loads of empty cans are easily lifted by a fork lift and loaded into trucks or railroad cars for shipping to the food processing plants.

The sardine cans in this plant are made on a separate line. The sheets are printed and varnished as usual, and strips are fed into the punch and press machines. The blanks move into a press section of the machine with dies that extrude the metal to make the oval or rectangular-shaped can. Excess metal is trimmed from the edges in another operation which also provides a rolled edge for the sealing operation. With this method of making cans, no solder is needed and, therefore, no soldering operation is involved.

The covers for sardine cans are made in similar machines, except that no extruding section is required. The blanks are therefore punched into the shape required, a groove is pressed into the blank, a sealing compound is added to the groove and then baked to set. The covers and cans for sardines are then packed in cartons for handling and shipping.

Materials

The tinned sheet steel accounts for about 60% of the total cost. Each customer specifies the weight of tin required, usually expressed in pounds of tin per hundred pounds of sheet steel, and this must be maintained as a minimum within certain limits. For example, on a typical order for 0.25 lbs. of tin per 100 pounds of tinned sheets, 0.50 lbs/100 lbs. (more than the order specified) is acceptable but no less than 0.22 lbs./100 lbs. can be accepted. The amount of tin used is carefully controlled for the customers requirements, which are based on the type of food content.

The tin plate does not cover the steel perfectly. There are many, very small bare spots. It would be too costly to use enough tin to cover the surface completely, so it is necessary to use varnish which is more economical. This is the reason that enamel is required on all inside surfaces to prevent the food products from making direct contact with the steel. Some cans have a quick retouch of enamel of the solder seam to cover any exposed steel, and others have the whole inside well sprayed as a final requirement.

There are perhaps 1000 different can types manufactured in this plant alone. This means cans have different dimensions, and vary in the weights of steel and enamel specified, where and how it is placed, and differ in the printing. All of this indicates the diversification of production facilities inherent in the process. In an emergency, most of this diversification could be done away with, by concentrating production on a few, multi purpose types of cans.

Material handling equipment

Heavy battery-operated forklift trucks are used to pick up the loaded two-ton pallets of sheet steel for the moving and delivery to process machines. Facilities for recharging batteries are maintained in the basement area, along with other repair and service equipment.

A complicated system of conveyors transfers the cans in process from machine to machine and then to the packaging unit. Gravity feed is most common but belt drives are necessary to elevate cans.

Roller conveyors are used for material leaving the sardine can machines and for moving the cartons to a loading position.

Processing machines and equipment

The manufacturing equipment is generally heavy and appears to be relatively invulnerable to missile damage from glass and other light materials. There are nine machines making can bodies of various lengths and diameters. The can machines are heavy frame units approximately 25 feet long and would not be seriously affected by shock or vibration from a blast unless it were strong enough to damage the building. Flying bricks and falling beams could damage mechanisms and shafts or break the frames. But since there are nine of these units in service, many with interchangeable parts, cannibalization could be used to help place machines in operation after a damaging blast.

The punch and forming press machines are very sturdy, built to withstand shock and vibration. Direct blast would not damage them; the only damage would be secondary due to missiles and falling structural members.

The roller conveyors are also sturdy and damage could come only from heavy missiles or falling material.

The endless chain in the baking oven is made of large, heavy links. Each line has a loop of wire attached which acts as a separator to support the varnished sheets during baking. The oven is approximately 90 feet long, and six feet in diameter, is fed by gas and has automatic temperature controls.

The printing presses are heavy-duty roll types to handle flat sheet. They are sturdy enough to withstand considerable shock or vibration and would not be damaged unless material fell across the units or missiles struck them.

Packaging machines and equipment

The packaging machines gather the cans and prepare them for wrapping. Men complete the wrapping and strap the stock by hand. The packaging machine is a lightly-built unit which would be damaged by any falling structural material.

Most of the other products are packaged by hand in packing boxes or cartons. However, as the ends leave the machines they are automatically stacked in single piles by means of stacking forms, to facilitate handling. These light metal forms are part of the production machine and could easily be damaged. Production could continue without these attachments but handling would require more personnel to package the product.

Sardine cans and covers are packed in cardboard cartons, making packages that are easily handled for moving and shipping.

Most material is shipped out in large vans especially for short hauls or local areas. Occasionally, shipments are made by rail for longer hauls.

6.2.3 Personnel

This plant usually works one eight-hour shift each day but could operate more shifts if the need arose. The personnel who operate the machine shop could be available to help the maintenance crews bring the plant into production if repair work required it after a nuclear blast. Plant personnel consist of the following.

Office	50
Engineering	10
Shipping & receiving	40
Packaging	40
Tin sheet varnish & baking	20
Can forming & processing	50
Machine shop	60
Maintenance	60
Steam plant	20
Total	350

6.2.4 Shelter (within plant)

The can plant had no fallout shelter and had made no provisions for one. The only area that may provide some protection at present is located in the north portion of the basement. But more excavation and construction may be necessary to provide satisfactory protection for extended periods.

6.2.5 Shutdown and startup (normal)

This plant used mechanical equipment throughout most of its operating process and as a result, most of the equipment can be started up and shut down independently. Each can line operates as a unit, and whenever it is necessary to stop the lines for checking, adjusting, or repair, the operators can stop them in a moment's notice.

6.2.6 Utilities (normal)

Water supply

Water for domestic use and boiler feed is supplied by city water mains which are well underground, beneath the frost line.

Electrical facilities

The electric power supply is completely dependent on an outside power supply and distribution system, which is comprised of a network of power lines extending out in several directions.

The electrical power is supplied at 4100 volts and transformed to 220 volts by transformers which have a maximum capacity of 900 KVA. The motors used throughout the plant are all rated at 220 volts and up to 10 HP maximum.

6.2.7 Repair and maintenance capability

A well equipped machine shop is located on the third floor of the factory building. Lathes, drill presses, shapers, milling machines and grinders are continually reconditioning worn parts and making replacement parts. The shop could be an asset to recovery after a blast.

6.3 VULNERABILITY ANALYSIS

6.3.1 Low pressure blast range (0.0 psi to 3.0 psi)

Glass failure will be evident at 0.1 psi, but there will be no delay in operation of the plant unless the fallout hazard is great enough to endanger working personnel. If the blast pressure reaches 0.5 psi, most glass will be shattered, although the missile damage will still not be very great, and at 1.5 psi, the stack will exhibit cracking of the mortar. A blast approaching 3.0 psi will shatter all the windows, and equipment will require cleaning, checking, repairing or replacement with new parts. The boilerhouse will receive the most damage, especially the gauges, meters, recorders and controls.

6.3.2 Medium pressure blast range (3.0 psi to 7.0 psi)

The stack will overturn at 3.0 psi, and there is an approximately equal chance of its falling on the boilerhouse or free of it. This raises the possibility of damage to the boilerhouse that would otherwise not take place until it collapsed at above 7.0 psi, in the high range of blast damage. The connections of the stack to the boilerhouse will also be damaged.

The cinder block walls of the main factory building will show cracking at 3.0 psi and will collapse at 4.0 psi, damaging equipment within the building. The warehouse walls will also collapse at 4.0 psi with damage incurred to the packaging equipment.

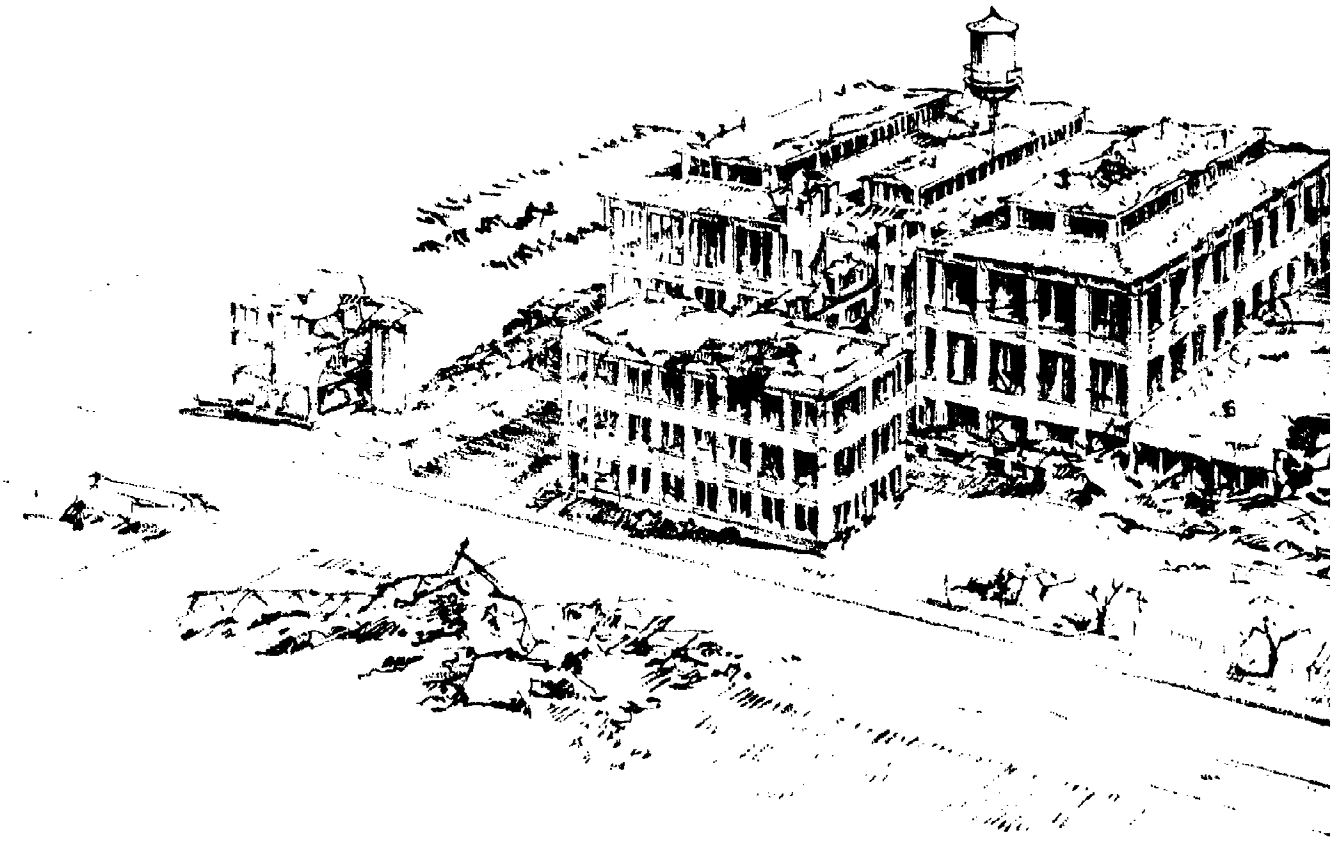
At 5.0 psi, the walls and roof of the office building will collapse and the frame of the warehouse will show moderate damage, all of which is in addition to the damage already done in the low range.

If the water tower were empty, which it seldom is, it would collapse at any pressure above 6.0 psi. When full, the tower will collapse at 7.5 psi. The chances of being part full are much greater and if one assumes that it averages to be about 2/3 full, it is still likely the tower will collapse below 7.0 psi. To lessen chances of collapse, therefore, it would be important to keep the water tower more than 2/3 full. Water could be supplied directly by the city for normal process use, but the extra water needed for fire protection would not be available if the water tower were not in use.

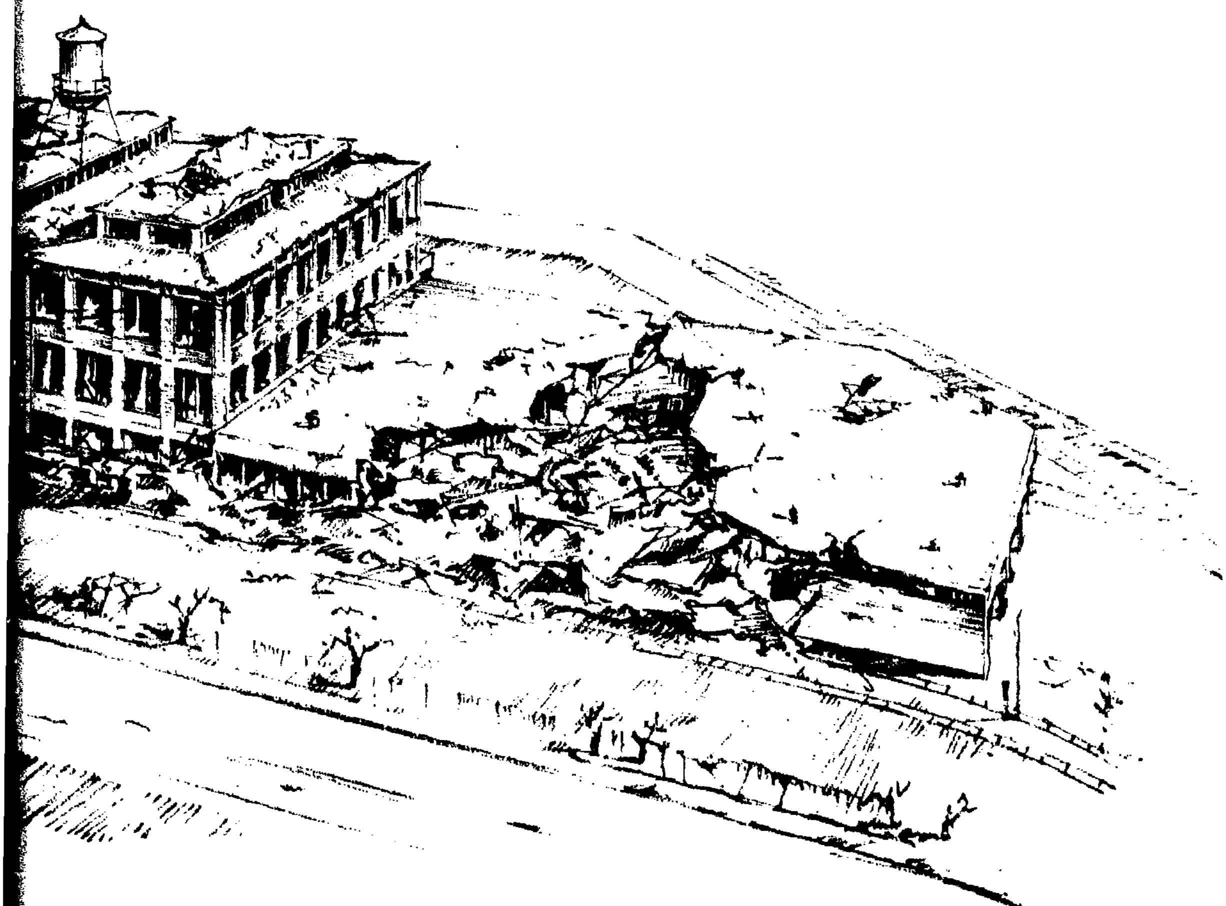
6.3.3 High pressure blast range (7.0 psi to 12.0 psi)

This range starts with the collapse of several buildings, as shown in figure 6-5.

Although all of these buildings may not fail simultaneously, the frames of the warehouse, boilerhouse and office building will collapse when overpressures approach 7.0 psi. The collapse of the warehouse frame will increase the damage to packaging equipment; boilers as well as motors and other fairly heavy equipment will be severely damaged. The office building and its equipment will be completely destroyed.



Damage to Metal-Container Pla



Metal-Container Plant at 7 psi Overpressure

Figure 6-5

The water tower when full will collapse at 7.5 psi and, depending on the direction of the blast, could damage process equipment below it or equipment in the machine shop. At 9.0 psi, the frame of the main factory building will suffer moderate damage which could cause damage to equipment due to shifting and misalignment of machinery.

At 12.0 psi, the frame of the main factory will collapse, making the destruction of the plant complete.

6.3.4 Thermal radiation

Thermal radiation could be hazardous to exposed personnel, but the damage to the plant would probably be negligible.

Paper used in the office building could ignite and start fires, which would be limited to the office building. Even though there is a physical connection to the main factory, the building materials used in this connection would not sustain a fire, thus removing the danger of fire to the main building.

6.3.5 Fallout

Besides being hazardous to personnel, fallout would contaminate all metal cans which were in process at the time of attack. This contamination of the cans would not be serious because they could be easily cleaned.

6.3.6 Shutdown

A rapid shutdown would not produce any damaging effects. The printing presses and bake ovens can stop anytime without damage, although some sheets might be overbaked and some underbaked. It would be best to turn off the gas supply by turning a main valve in the basement, to prevent explosions or fires due to leaks that may develop.

The boilerhouse generally supplies heat for buildings and for process purposes. It too could be shut down at any moment by the operator, and left to cool down slowly. If there is no blast damage, it could be started and resume heating operations as usual. If there is much damage, the boilerhouse could be left to cool down normally and very little harm would be done as long as sufficient water could be maintained in the boiler tubes. In winter, some means of preventing pipes from freezing would have to be provided. This could be done by a shutoff and drain valve in the main water supply. The water system should be studied to make sure all low points are properly drained just for such an emergency condition.

6.3.7 Bottlenecks and weak links

The most vulnerable bottleneck in this plant is the elevator system for delivering materials to the third floor. All materials must be picked up by lift trucks on the ground floor, carried by the elevators up to the third floor, and delivered as required. If for any reason the elevators cannot operate, the supply of material would soon run out and stop production. Some outside means would be necessary to supply material to the third floor, and this could cause considerable delay until temporary elevator equipment could be obtained and installed.

Another difficulty that may cause early or unnecessary delay is the vulnerability of the glass walls of the boilerhouse, which will break up at very low pressures. Any damage that may result from glass, debris and missiles could hold up process work until repaired. Parts such as gauges, meters, controls and small diameter steam piping should be protected to prevent damage and delays.

6.4 RECOVERY

6.4.1 Summary of damage

Summaries of damage to structures and processing equipment are found in tables 6-1 and 6-2.

6.4.2 Spare parts and cannibalization

The plant carries a good stock of spare parts, sufficient for normal requirements for six months to a year, with periodic checks and stocktaking to ensure that no shortages occur. Under emergency conditions, this would go a long way toward supplying the parts necessary for recovery.

Machine shop equipment could be damaged as well as that used in processing, but most of it is rugged, and enough would survive the lower blast damage range or even the medium blast range to carry out many important repair requirements.

Some production lines in the processing system have several identical or similar machines that use the same parts. These machines can be cannibalized to initiate the early repair of some units and start production with those repaired first, leaving those machines badly damaged until the last when parts can be supplied or replacement made.

6.4.3 Initiating emergency operation

To place the plant on emergency operation after any blast, it is necessary to consider only the equipment necessary for production. This includes the cleaning of process equipment, the removing of structural material to free equipment and sufficient reconstruction to protect the product in process.

Operation following low blast damage (0.0 psi to 3.0 psi)

Very little repair is required in this range to bring the plant up to emergency operation. Dust and fallout will have to be removed from equipment and metal cans which were in the processing system at the time of the blast. Missile damage will require repairing of all gauges, meters and controls in the boilerhouse and throughout the plant. The connection between the stack and boilerhouse will require repair.

Operation following medium blast damage (3.0 psi to 7.0 psi)

Although the plant is extensively damaged by the collapse of the stack on the boilerhouse, and the collapses of the office building and main factory walls, emergency operation concerns only the main factory.

After clearing away the rubble at the factory, the equipment will require assessment as to damage and the repair effort required to place the processing system on an emergency basis. Most of the machines are rugged and will

Table 6-1 Summary of Damage to Structures at Metal Can Plant

Pressure (psi)	Stack	Main Factory Bldg.	Ware-house	Office Bldg.	Water Tower	Boiler-house
0.1		glass cracking	glass cracking	glass cracking		glass cracking
0.5		glass failure	glass failure	glass failure		glass failure
1.0						
1.5	cracking					
2.0						
3.0	overturns	cinder block walls crack				
4.0		cinder block walls crack	walls collapse			
5.0			frame moderate damage	roof & walls collapse		
6.0					(empty) collapse	
7.0			frame collapse	frame collapse		frame collapse
7.5					(full) collapse	
9.0		frame moderate damage				
12.0		frame collapse				

Table 6-2 Summary of Damage to Processing Equipment at Metal Can Plant

Structural	Critical Overpressure	Processing Equipment
Glass cracking	0.1	dust and fallout.
Fenestration collapse	0.5	glass and missile damage to equipment.
Stack cracking	1.5	connection to powerhouse damaged.
Stack overturns	3.0	connection to powerhouse damaged.
overturns on powerhouse		damaged controls, piping and auxiliary equipment.
Main factory building cinder block walls collapse	4.0	missile damage to piping, presses, tanks and filter equip.
Warehouse walls collapse		packaging equip. damaged.
Warehouse frame moderate damage	5.0	packaging equipment heavily damaged.
Office building frame damage and roof and walls collapse		much debris and office equip. badly damaged.
Water tower (empty) collapse		piping and tower damaged.
Warehouse frame collapse	7.0	package equipment badly dam.
Boilerhouse frame collapse		meters, recorders, control panels, piping and auxiliary equipment demolished.
Office building collapse		files, desks & equipment demolished.
Water tower (full) collapse	7.5	pipe connection, steam line demolished.
Main factory frame moderate damage	9.0	tanks, filters, presses, piping meters and controls badly dam.
Main factory frame collapse	12.0	all equipment demolished.

require a minimum amount of repair, but the roller and belt conveyors will be severely damaged and require extensive repairs and many replacement parts. The packaging machines will also be severely damaged and will require considerable replacement parts and repair.

An important phase of the repair in this range would be the elevators which carry the materials from the ground floor to the third floor. As noted in an earlier section, without the elevators, production would stop unless temporary means of lifting the material to the third floor were provided.

Operation following high blast damage (7.0 psi to 12.0 psi)

In addition to the minimum amount of work required in the low and medium ranges, the following efforts will be required to place the plant on emergency operation for the high range.

The machine shop equipment will have to be repaired and replacement parts obtained after the rubble is cleared away. The main factory equipment would require rebuilding and repair after rubble is cleaned up.

The loss of the warehouse, boilerhouse or office building between 7.0 and 9.0 psi, would effect production in varying degrees but would not necessarily stop it altogether, and by some means production could continue while repairs were being made if this were necessary.

Without packaging equipment, the plant could operate by hand packing the cans and moving the cartons directly to the loading area from the production floor. Thus, production could continue, but on a limited scale.

Missile damage to the main factory equipment will be extensive, but cannibalization can help to get a complete process line ready to obtain an early start on production. However, this assumes that electric power and water will be available. Power lines may collapse around 4.0 psi, and new power lines will have to be provided before electricity would be available to operate any part of the plant. If only a portion of the transmission line is damaged, electricity will probably be available as soon as the plant is ready for operation.

6.4.4 Shortcuts

As an emergency measure, the only phase of the metal can processing which could be eliminated would be the application and baking of the varnish coating. Without the varnish coating the food contained in the can would have to be removed or eaten at the time the can was opened, otherwise the food would spoil rapidly from being in contact with the uncoated portions of the can.

6.4.5 Utilities

Water supply

Water for the plant comes from city mains, and so the pressure depends on the city water supply. With all pipelines underground, they should still be intact as long as the plant is in condition to operate. If a city water supply plant should be damaged, it may hold up operation of the can plant for lack of water, but as for the plant and the immediate area, the water supply should be satisfactory as long as the plant is in a position to use water.

Electric power

The power supply is completely dependent on facilities provided by the local power supply and distribution system. A network of power lines extends out in several directions to other sources of supply, making it almost certain that sufficient power will be available as soon as local lines are repaired. This indicates that whenever the plant is declared ready to operate, electric power could be made available as required.

6.4.6 Repair required to resume normal operation

Low blast pressure range

The major portion of the work is the cleaning up of dust, dirt and pieces of glass after which missile damage to instruments and controls can be repaired. The stack will need repointing of the mortar joints, and its connection to the boilerhouse will have to be inspected.

Medium blast pressure range

The debris from the overturned stack must be cleared away before a new foundation is constructed and the stack rebuilt. With the possibility of the stack collapsing on the boilerhouse, additional boilerhouse repair could be required in this range.

The cinder block walls of the main factory building will need repointing at a pressure of 3.0 psi. At 4.0 psi, the collapsed walls will have to be rebuilt and all equipment affected by the collapse will require checking and repairing. The packaging equipment at the warehouse will require extensive repair and replacement parts. and the walls will need rebuilding at 4.0 psi.

Except for the frame, the office building will require complete rebuilding and the moderate frame damage at the warehouse could be corrected by installing new bracing.

At 6.0 psi, the water tower will require rebuilding and repiping.

High blast pressure range

The frames of the warehouse, boilerhouse and office building will have to be rebuilt at 7.0 psi. Equipment in these buildings will require repair and reconstruction, particularly the packaging machinery which is not as rugged as most of the other machinery at the plant.

At 7.5 psi, the collapsed water tower will require complete rebuilding, utilizing any parts or piping which could be salvaged. The main factory frame will need repairs and equipment in the building will require repair and realignment. Up to 12.0 psi, the main factory is repairable. Rubble should be cleared away from the machine shop at the same time it is being done at the processing system, because the machine shop would be an important asset in the repair of the processing equipment.

At 12.0 psi or above, it is uneconomical to repair the plant because of complete destruction.

6.4.7 Substitutes

Substitutes for the metal can include glass or carton containers which are manufactured at other plants. The metal can plant which was studied in this report cannot manufacture cardboard cans, so there would be no possibility of substituting cardboard in the event that the supply of tinplate were cut off.

6.4.8 Increased production capability

Provided enough machine operators survived the attack, and damage is not too extensive, the plant could go on a three-shift basis in the processing and machine shop areas.

6.4.9 Estimated man-days required for repair for each level of blast pressure

The following charts indicate the estimated repair effort in man-days required for emergency operation and complete recovery to resume normal operation. The Recovery Chart for the metal can plant, figure 6-6, indicates graphically the information contained in the repair estimate charts.

METAL CAN PLANT

Low Blast Damage Range 0.0 to 3.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
0.1	fallout, dust & glass cracking	clean up	labor	20	10	200
0.5	all glass broken	replace glass	carpenters	35	10	350
1.5	stack cracking	check and repair	engineer tradesmen	40	10	400
			Structural			950
	PROCESS					
0.1	fallout & dust					
0.5	broken glass and missile damage	clean mach. check for dam & repair	mechanics labor	22	10	220
1.5	stack cracking	check power-house connections	technicians labor	2	10	20
			Process			240
			Structural			950
		Total man-days for Low Range				1,190

METAL CAN PLANT

Low Blast Damage Range 0.0 to 3.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
	clean up dust & glass shards			5	10	50
	Process					
	clean equipment and check for damage			1	10	10
		Total man-days for Low Range				60

METAL CAN PLANT

Medium Blast Damage Range 3.0 to 7.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
3.0	Stack overturns	rebuild stack	engineers masons labor	10	60	600
	Cinderblock walls of main factory bldg. crack	repair wall	masons	25	60	1500
	Stack collapses on powerhouse*	repair or rebuild	engineer & tradesmen	25	60	1500
	*50-50 chance of occurring in this range					
4.0	Cinderblock walls of main factory bldg. collapse	rebuild walls	masons laborers	50	60	3000
	Warehouse walls collapse	rebuild walls	masons laborers	50	60	3000
5.0	Frame warehouse moderate damage	repair frame	engineer tradesmen labor	25	60	1500
	Frame office bldg. moderate damage	repair frame	engineer tradesmen labor	25	60	1500
	Roof of office bldg. breaks in	rebuild roof	engineer tradesmen labor	25	60	1500
	Walls office bldg. collapse	rebuild walls	engineer tradesmen labor	50	60	3000
	Water tower (empty) collapse	rebuild tower	engineer tradesmen labor	10	60	600
			Structural			17,700

METAL CAN PLANT

Medium Blast Damage Range 3.0 to 7.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS					
3.0	Stack overturns	new connections to powerhouse	technicians tradesmen labor	10	60	600
	Missile damage in powerhouse	check all equip. repair all gauges, indicators, recorders and control equipment	tradesmen labor	10	60	600
	Stack collapses on powerhouse *	complete overhaul of equip. repair and replace parts	engineer tradesmen labor	35	60	2100
	* 50-50 chance of occuring in this range					
4.0	Main factory walls collapse	clean dust, dirt, debris, overhaul equipment	tradesmen labor	10	60	600
	Warehouse walls collapse	clean up debris check and repair packaging equipment	tradesmen labor	5	60	300
5.0	Warehouse frame-moderate damage	check added missile damage	tradesmen	1	60	60
	Office bldg. moderate frame damage, roof & walls coll.	clean up debris	labor	1	60	60
	Water tower (empty) collapse	replace piping connections	tradesmen labor	5	60	300
		repair and replace equipment in bldg. under water tower	mechanics labor	10	60	600
		Process				5,220
		Structural				17,700
		Total for 3.0 psi to 7.0 psi				22,920
		Total for Low Range				1,190
		Total man-days for Medium Range				24,110

METAL CAN PLANT

Medium Blast Damage Range 3.0 to 7.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
4.0	clean up rubble at main factory			20	25	500
	Process					
4.0	clean up dust, dirt and debris on equipment, overhaul and repair equipment			24	25	600
		Total for 3.0 psi to 7.0 psi				1,100
		Total for Low Range				60
		Total man-days for Medium Range				1,160

METAL CAN PLANT

High Blast Damage Range 7.0 to 12.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
7.0	warehouse frame collapses	rebuild	engineer tradesmen labor	40	100	4000
	boilerhouse frame collapses	rebuild	engineer tradesmen labor	20	100	2000
	office bldg. frame collapses	rebuild	engineer tradesmen labor	40	100	4000
7.5	water tower (full) collapses	rebuild	tradesmen labor	4	100	400
9.0	main factory frame moderate damage	repair	masons laborers	50	100	5000
			Structural			15,400
	Note: At 12.0 psi or above it is no longer economical to repair the plant					
12.0	main factory frame collapses	rebuild				
	PROCESS					
7.0	warehouse collapses	repair and replace equip.	mechanics	2	100	200
	boilerhouse - coll.	repair & re-place equip.	engineer technician tradesmen labor	20	100	2000
	office bldg. coll.	repair & re-place equip.	labor	2	100	200
7.5	water tower collapses	check increased missile dam.	labor	2	100	200

METAL CAN PLANT

High Blast Damage Range 7.0 to 12.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS (Continued)					
9.0	main factory frame moderate damage	check over equip. for extensive damage	tradesmen labor	50	100	5000
			Process			7,600
			Structural			15,400
		Total for 7.0 psi to 12.0 psi				23,000
		Total for Medium Range				24,110
		Total man-days for Medium Range				47,110
12.0	main factory frame collapses	repair, rebuild replace all equip.				

METAL CAN PLANT

High Blast Damage Range 7.0 to 12.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
9.0	Repair main factory building frame			100	50	5,000
	Process					
	Clean, overhaul and repair all equipment in main factory bldg.			100	50	5,000
		Total for 7.0 psi to 12.0 psi				10,000
		Total for medium range				1,160
		Total man-days for high range				11,160

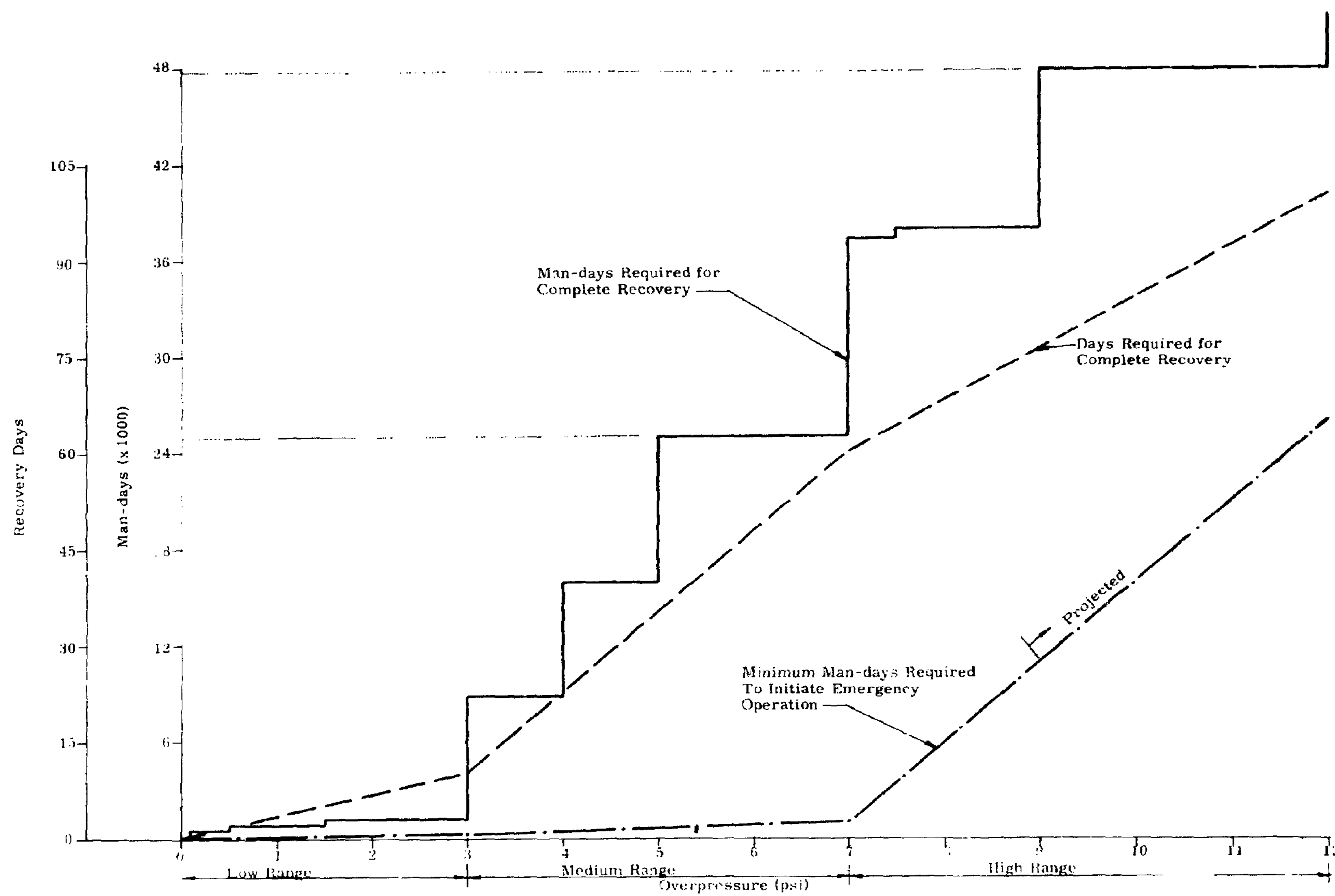


Figure 6-6 Recovery Chart - Metal Can Plant

6.5 WAXED CARTON PLANT

6.5.1 General description

The plant is located in the Needham Industrial Complex, on the outskirts of Boston. The Route 128 interchange in Needham Heights provides excellent connections in all directions, and rail connections are provided by a siding branch to this location. The office, power plant and manufacturing facilities are located in separate one-story buildings. The manufacturing plant is modern in construction with all space and facilities under one roof, and outside walls are adequately windowed. The interior is free of columns and has sufficient head room for all the equipment. The air-conditioned plant and equipment are new and modern in design, and automatic operation is provided wherever possible or suitable. The buildings are illustrated in figure 6-7.

The plant was originally designed for making paper cartons, but when the demand arose for more beverage cans in the Boston area, two additional production lines were installed for this purpose. As metal cans are not this plant's primary product, they were not studied here; the can study was made at the Portland plant.

This plant was built in 1954, and expanded in 1957 to incorporate the added lines for the manufacture of beer and beverage cans. The can manufacturing facilities are similar to those in Portland, except that more automation has been incorporated, and the beverage cans require an application of enamel after the cans are sideseamed. The flat stock for the Boston plant is enameled and lithographed elsewhere, whereas in the Portland plant, such facilities are in-plant operations. The carton-making machinery is somewhat lighter than the can-making equipment, but cannot be considered fragile.

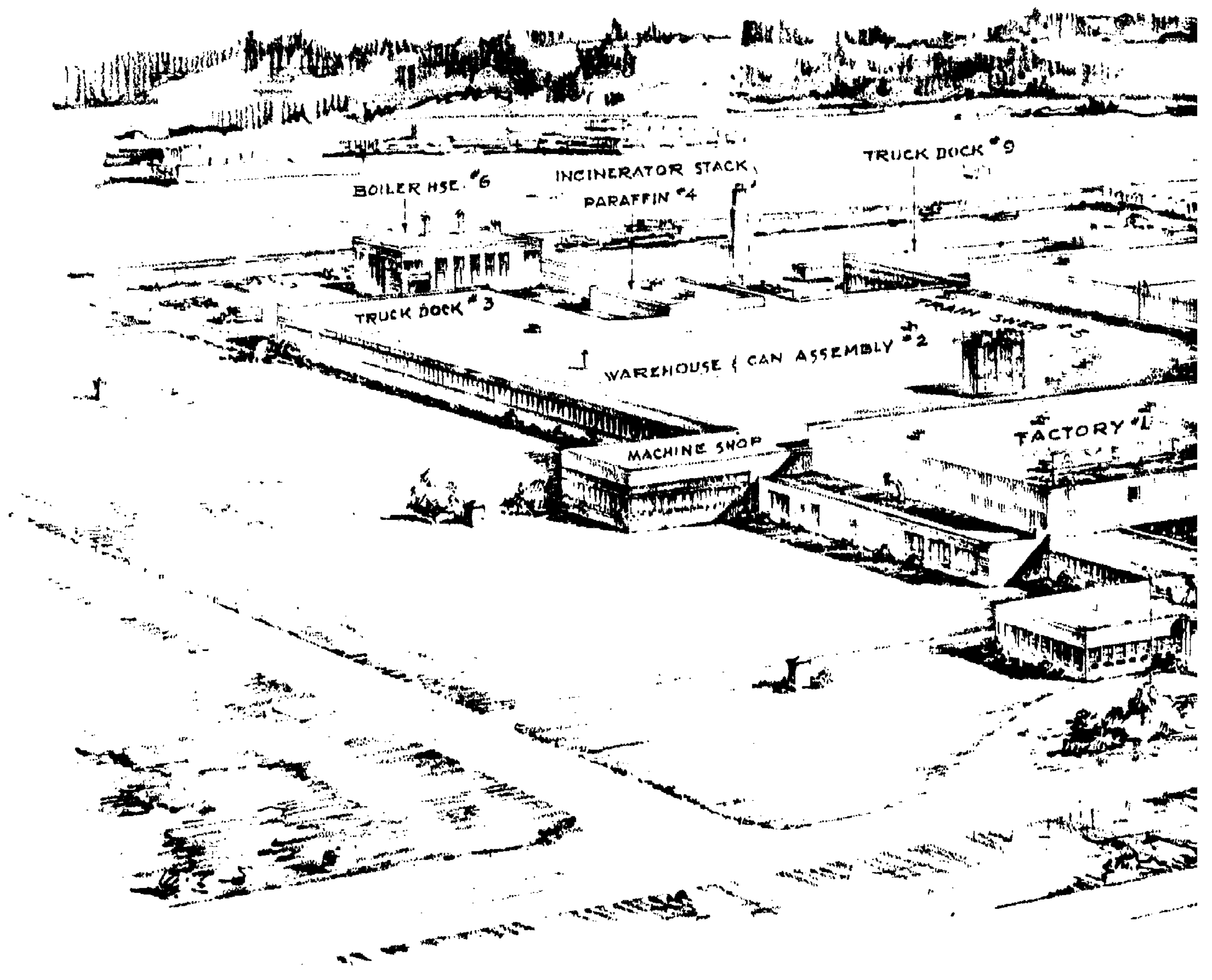
This plant is entirely of steel and metal curtain wall construction, with a large glass area in most walls. Contrasting sharply with the Portland plant, the Needham Heights plant is spread laterally in nine interconnected, one-story buildings, plus a boilerhouse. The buildings, built in 1954 to 1957, adequately fulfill their planned manufacturing functions.

6.5.2 Operation

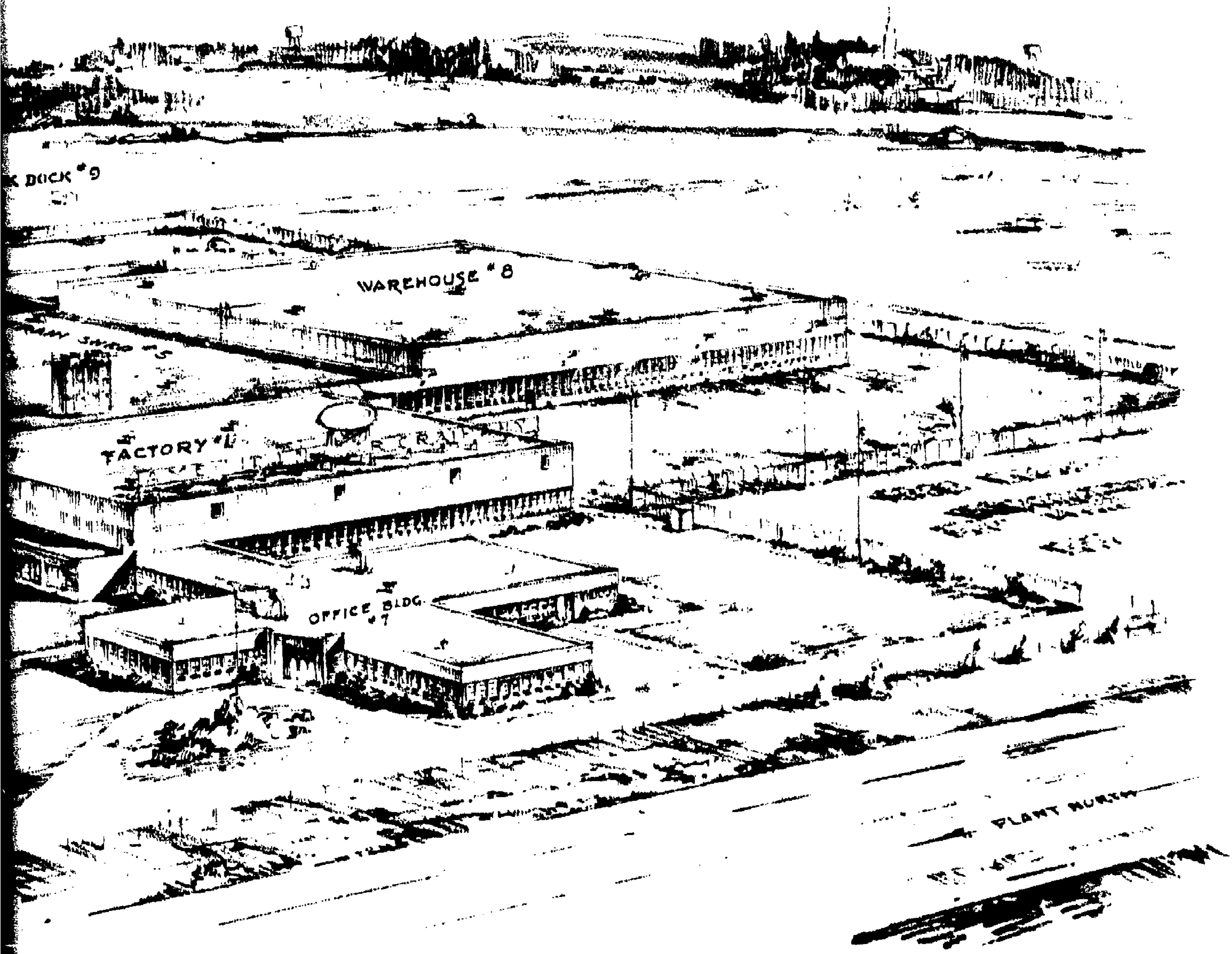
Paper is received in large rolls of approximately 500 lbs., of which a considerable amount is kept in storage, and sufficient stock is maintained to keep the plant in operation for approximately 100 days.

There are six automatic machines that make the covers for the half-pint milk cartons. A 4-foot diameter roll of paper approximately 6 inches wide is fed into each machine. The machine cuts the strip in half and makes two lids at a time. Each machine produces 200,000 covers per day.

Two other automatic machines in a similar process make covers for the half-gallon size cartons. These lids pour out of the machines into piles, which are picked up periodically by hand and placed in boxes. They are then placed in metal tote boxes and from there are placed on pushcarts. When required, they are transported to the carton-forming machines and stacked on the feeder for use.


TRUCK DOCK #9
BOILER HSE. #6
INCINERATOR STACK
PARAFFIN #4
TRUCK DOCK #3
WAREHOUSE & CAN ASSEMBLY #2
MACHINE SHOP
FACTORY #1

Waxed-Car



Waxed-Carton Plant

Figure 6-7

Two printing presses are used for all the carton printing; one is set up for the pint cartons, and the other is used for printing the half gallon sizes.

Glue is also printed on the paper for sealing all joints. Large rolls of paper are fed to each printing press, then cut to size, and all joints are sealed. Four rolls of paper pour out of the machine simultaneously; the blanks are stacked as they leave the machine, then placed on shelves in specially made carts.

The blanks are then taken out of the storage carts and placed in feed piles on a carton-forming machine, which takes one blank at a time. The blanks are folded, placed in position, and heat is applied to the glue on the formed cartons. From here the glued cartons are fed through a special conveyor to a large waxing unit approximately 40 feet long, 10 feet high, and 8 feet wide. This unit has a vertical divider down the middle. One half is steam-heated and has a hot wax dip bath maintained at 160°F. The other half has a refrigeration unit to keep the space cold.

In the waxing unit, each carton is positioned and held separately by an endless chain; this same chain carries the carton into a bath of hot liquid wax, completely submerging it for a few seconds. As the carton is carried around the pulley at the far end of the unit, it is turned upside down and all wax is drained out at the spout. The heat in this space keeps the wax in liquid form, so a completely drained unit arrives at the feed end of the chain where it is removed. It is then transferred to the other half of the machine onto another chain which carries the cartons, on three passes, the full length of the machine for the waxed carton to cool completely, before it is released and removed at the far end. The cartons are then placed in a large paper wrapper which is sealed and put on a conveyor belt for transportation to the warehouse for storage or for transfer to the shipping area for loading on trucks and railroad cars.

During the packing operation, the cartons are inspected by the packer and any that are not satisfactory are rejected.

At any one time, there are hundreds of truckloads of packaged cartons stacked in the warehouse, ready for shipment.

Material handling equipment

Forklift trucks are used extensively for the handling of heavy paper rolls. In the manufacture of cartons, paper rolls are the largest individual material used.

This plant also makes metal cans, and the lift trucks do double duty in that they also handle sheet steel, eliminating the necessity of other types of handling equipment.

The finished paper carton packages are moved by conveyor belts to either the loading docks or to the warehouse. At the loading dock, movable roller conveyors allow easy movement of equipment for placement into either trucks or railroad cars.

The finished paper carton packages are moved by conveyor belts to either the loading docks or to the warehouse. At the loading dock, movable roller conveyors allow easy movement of equipment for placement into either trucks or railroad cars.

The truck loading dock is equipped with a special dock leveler which keeps the dock at the same level as the truck body bed, even as the truck springs compress as the load on the truck increases.

Processing machines and equipment

The printing presses are heavy machines and would not be easily moved by a blast, but rather would be vulnerable to flying missiles and falling building materials.

The cover-making machines and the carton-forming machinery are heavy, strong units that will survive blast pressures without much damage. Flying material could damage the mechanisms and operating parts, throwing the units out of adjustment.

The waxing unit, on the other hand, appears to be vulnerable to blast, and the machine could be pushed over, the sides caved in, with consequent damage to the frame. The conveying equipment is strong but may be damaged by the failure of the housing and framework. The heating equipment and refrigeration units would stand the blast, but would also be easily damaged by falling equipment or flying materials.

The feeding mechanisms on each machine are not likely to be damaged by blast but could be damaged by missiles, and would require a great deal of repair, replacement and adjustment.

Packaging machines and equipment

The packaging equipment is generally very simple, with the main operation carried out manually. Stands are built and arranged to hold the packages for the packers. These stands can be easily knocked out of shape and would require replacement. If necessary, a few more persons could be brought in to handle the product and continue packaging it.

6.5.3 Personnel

The carton plant works two or three shifts per day under normal operating conditions, depending on production requirements.

Some personnel are usually on duty at all times, but on weekends and holidays the number in the plant may be small.

Equipment operators usually start up machines to initiate production following any shutdown period, and their experience would be valuable after a nuclear blast as well. The maintenance and machine shop personnel would be needed to carry out cleaning and repair of equipment to help initiate recovery.

The overall personnel requirements consist of:

Office	13
Operations	187
Storage / Shipping & receiving	30
Steam plant	5
Machine shop	10
Maintenance	30
Total	275

6.5.4 Shelter (within plant)

The plant has no provisions for a fallout shelter, but a tunnel beneath the floor of the main plant could be used for this purpose. However, the protection factor should be checked before this is relied upon to any great extent. With some new excavation and construction added to this facility it would likely result in a safer area for fallout protection.

6.5.5 Shutdown and startup (normal)

The carton plant is shut down periodically for holidays. Printing presses can be shut down at any time without affecting any other later process, as can the carton forming machines. However, the waxing unit to which the formed cartons are fed should be emptied of cartons before the wax is drained away to the storage tanks. All other equipment can be turned off at any time although production lines are usually run until cleared of process material.

The process can be started up without much delay. The chief requirements are heating the waxing unit before adding new wax and heating the bath to the proper processing temperature. The cooling side of the waxing unit must also be turned on long enough to bring the space down to the proper chilling temperature before manufacturing can begin. The pipes throughout the plant carrying wax are electrically heated, and would present no problem.

6.5.6 Utilities (normal)

Electric power

Electric power is supplied by the local power authority and distributed throughout the area to all plants, on overhead lines.

Water supply

Water is supplied by the city and all piping is well underground.

Steam

Steam is produced in their own boilerhouse, separate from the main plant but only a short distance away.

The plant is located on a rise of ground and drainage from the area is very good.

6.5.7 Repair and maintence capability (normal)

The plant has a large well-equipped shop for repair and maintenance work. All the equipment is serviced by plant personnel. A stock of spare parts is maintained to provide for the plant's normal requirements and to prevent any delays in production.

6.6 VULNERABILITY ANALYSIS

6.6.1 Low pressure blast range (0.0 psi to 2.5 psi)

At or near 0.1 psi, windows will crack and the extensive glass areas in this plant will be subject to failure at about 0.5 psi. As a result of this failure, pressure and winds will be admitted into the building, and direct blast will subject some of the equipment to blast damage. The waxing unit which is essentially a large hollow container would either blow over or the sides of the tank would buckle. Most of the other process equipment is heavy, open-construction type machinery and a direct blast would have little effect unless very high pressures were experienced. As the blast travels through the warehouses, some supplies will be scattered and packaged cartons ready for shipment will be tossed about.

Missile damage over the low range will be nil at the very low pressures but at or near 2.5 psi, damage could be quite extensive. Broken glass, siding, and loose material flying around inside the plant would damage equipment.

The buildings will generally stand up satisfactorily in this range, except for the roof of the paraffin building #4. This will tend to crack at any pressure greater than 1.0 psi. Pieces of concrete will break loose and fall on equipment before total roof collapse takes place near 2.5 psi.

6.6.2 Medium pressure blast range (2.5 psi to 4.0 psi)

Near 2.5 psi, a number of failures will take place and the new damage will greatly increase the amount of work involved for repair and recovery.

The west section of factory building #1 will fail if the blast comes from either the north or south, and obviously (if there is any blast) there is an appreciable chance of this happening. If it did, machinery would be subject to damage from falling material as well as missile effects from glass, siding and loose material in the area.

Warehouse #2 will suffer general failure. The paraffin #4 roof will collapse, as will the south portion of warehouse #8 with an east or west blast, and the roof of drum storage building #10.

At 3.0 psi or higher, another group of failures will take place. Truck docks #3 and #9 will receive moderate damage; the walls will collapse in paraffin building #4; office building #7 will sustain cracking in the roof; and the walls of drum storage building #9 will probably fail.

6.6.3 High pressure blast range (4.0 psi to 7.0 psi)

At or near 4.0 psi, a number of damaging events take place with some buildings showing moderate damage and some failure or collapse. At 5.0 psi, additional buildings will be added to the list of those moderately damaged and at 6.0 psi or more, several of these buildings will finally collapse, leaving only the boilerhouse standing. But with a blast of 7.0 psi or greater, the boilerhouse too, will collapse.

With its failure, all facilities are collapsed or demolished, and this is the point at which repair will not be practical. A new, completely rebuilt facility will be necessary.

Figure 6-8 illustrates damage and building failures at the 4.0 psi level of over-pressure. Factory building #1 will undergo general failure and collapse, truck docks #3 and #9 will collapse, paraffin storage #4 shows moderate frame damage, train shed #5 and warehouse #5 will experience general failure, and drum storage #10 will show moderate frame damage.

The general failure of factory building #1 will incur a great deal of damage to heavy machinery and parts when the walls and roof structure collapse. The platform equalizers at the docks would suffer slight damage.

The paraffin building #4 will have moderate frame damage at 4.0 psi, with material from roof and walls causing extensive damage to piping and light equipment. It is likely that electric power would fail for a period of time at pressures of 4.0 psi and above.

The train shed and warehouse will suffer general failure causing damage to rolls of paper (for cartons) and destroying the packaged cans and cartons which will be ready for shipment. The frame of drum storage building #10 will be moderately damaged.

Further failures will take place if blast pressures reach or exceed 5.0 psi. The boilerhouse #6 frame will show moderate damage and office building #7 will collapse.

Damage to the boilerhouse frame will cause piping and equipment tied into it to be damaged and the collapse of the frame of office building #7 will demolish all equipment contained in the building.

The paraffin building #4 will collapse completely at 6.0 psi, the boilerhouse walls will collapse, adding to the debris and damage that was indicated at lower blast damage levels, and the drum storage building #10 will also fail completely. At this stage the only building still standing will be the boilerhouse. At a blast pressure of 7.0 psi or greater, it is expected to collapse too. Therefore, at somewhere near 7.0 psi, all facilities will have collapsed and the plant will have to be completely rebuilt.

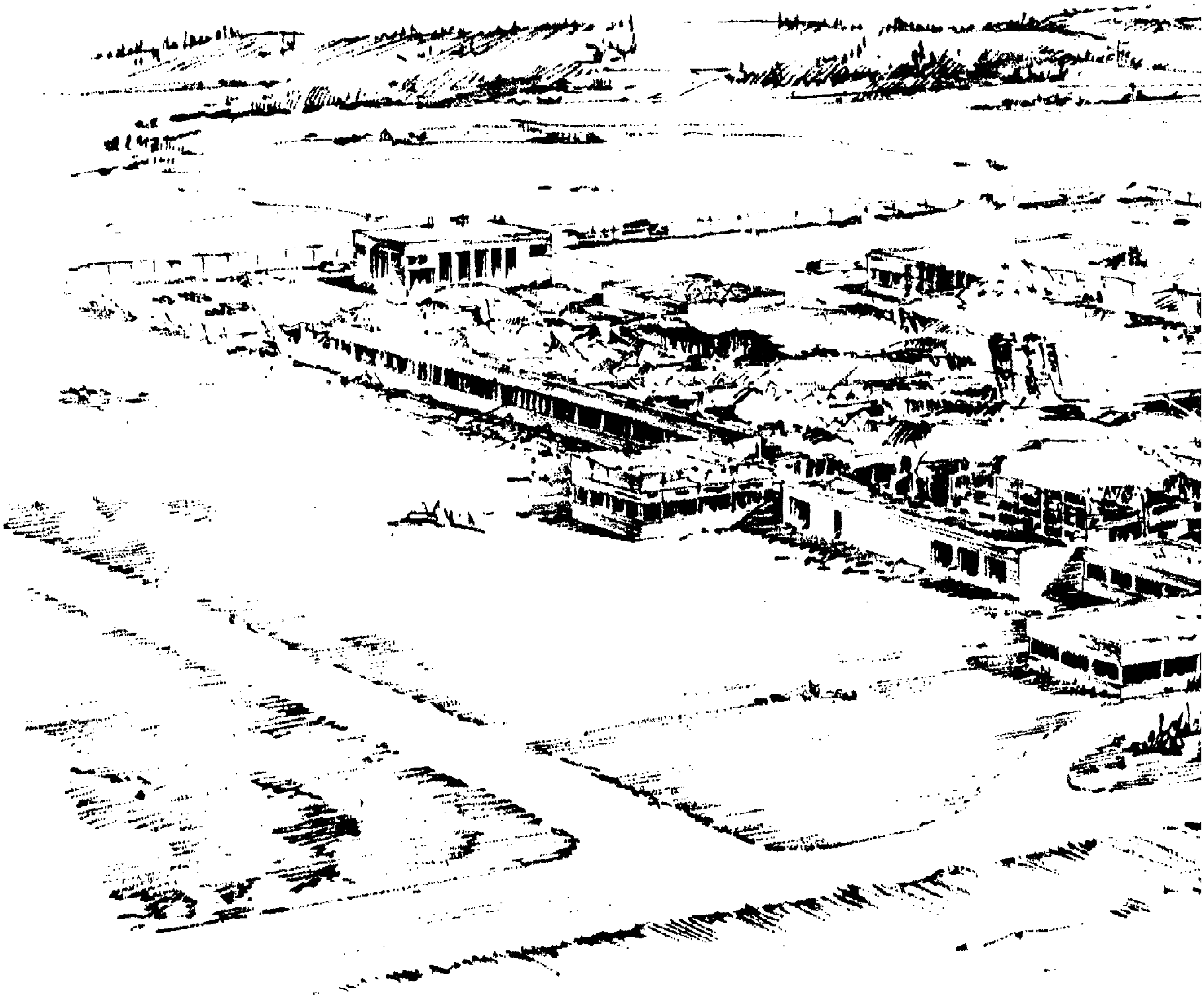
Equipment throughout the whole plant will be so badly damaged with falling beams, parts and by missile damage of flying glass, siding, and other free material, that with blasts near 6.0 and 7.0 psi, the whole area will be demolished, and will not be economically feasible to repair.

6.6.4 Thermal radiation

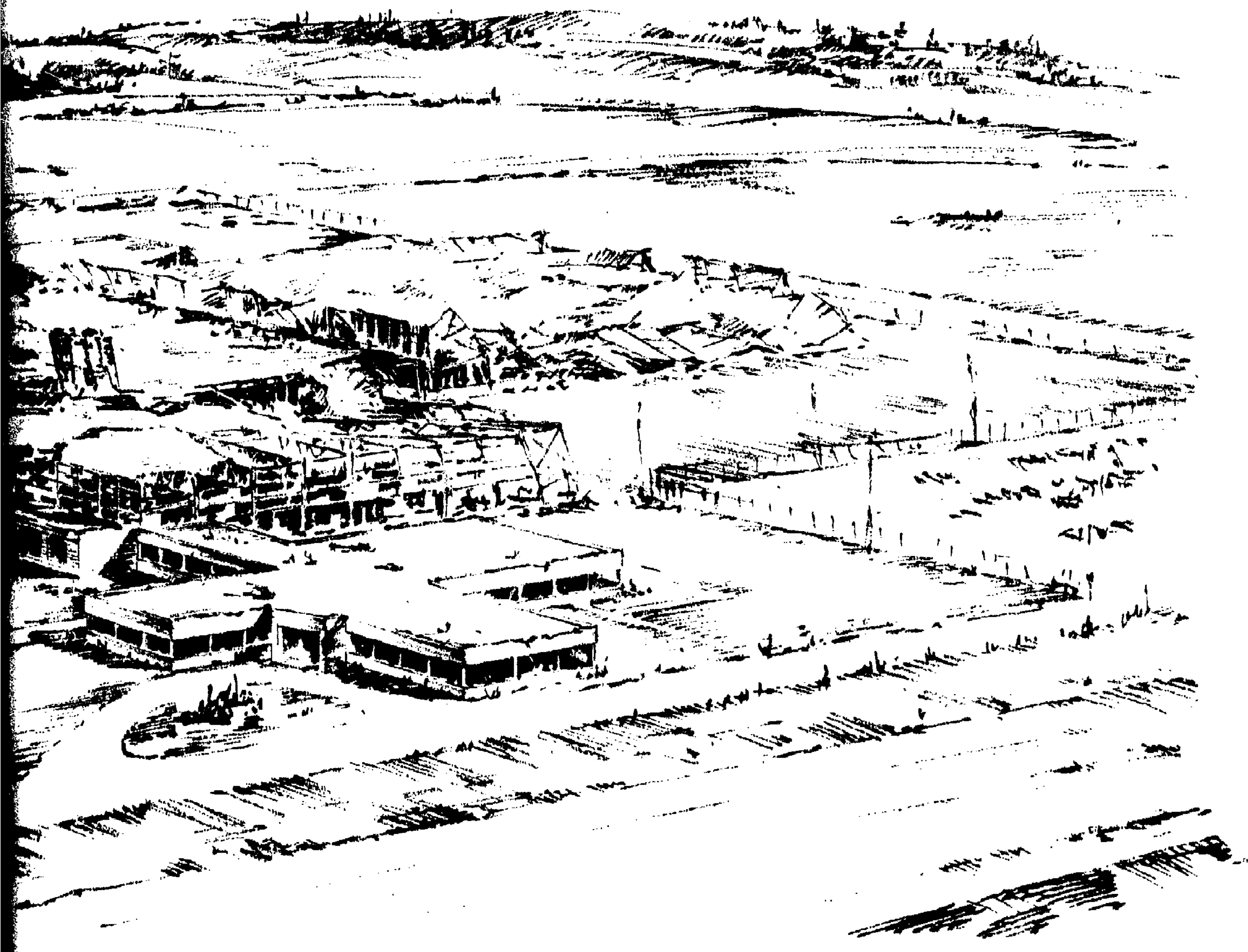
Paper in the office building could ignite and start fires, which probably would not spread to factory building #1 and into the remainder of the plant. The plant sprinkler system, the modern, relatively fireproof construction, and normal good housekeeping practices tend to prevent any fire spread.

6.6.5 Fallout

As is the case with the metal can plant, the fallout problem, except for its effects on exposed personnel, should be minimal. The cartons could be cleaned easily without damage, since they are protected by a wax coating.



Damage to Waxed-Cart



to Waxed-Carton Plant at 4 psi Overpressure

Figure 6-8

6.6.6 Shutdown

The plant process facilities can be shut down at any moment without disturbing or damaging equipment. It would be best to shut off all motors if warning time permitted, and all gas flames for heating in the process operation should be turned off to reduce fire hazard, and the main gas valve should be turned off to prevent leakage from broken pipes. This is a point that should be stressed in all cases. If the main valves are shut off, soon all flames will go out as the gas in the pipes is consumed. This eliminates the possibility of any gas flames being left burning and later igniting fires. The boilerhouse should be shut down before being abandoned, and this could be done in a matter of minutes, by turning off all the operating switches. This would give the boilers a chance to cool down normally, without damage, if no other failures took place.

6.6.7 Bottlenecks and weak links

The printing operation could be eliminated, but because the glue is placed on the carton blanks by the printing machine, which also cuts the blanks to size, the sheets must be run through the machine even if no printing is done.

Wax is stored in large tanks in a building adjacent to the railroad siding, which has one track entering the building. These tanks are kept heated and the wax is kept liquid, for free flow in piping to the waxing machine. The pipelines are electrically heated, and loss of electricity will cause all wax in the piping to cool and solidify.

It would take one or two days of maximum electric current in the pipelines and tanks to melt the wax so that it could flow again. This could be considered a bottleneck only if blast damage were so light that less than a day or two would be required for cleanup and repair. Otherwise, the wax could be melting, with little attention, while necessary repairs are in progress. The time required would depend to a certain extent on ambient temperatures. Usually the operators are instructed to check, clean and oil the machines before startup on production work, and normal practice should take care of startup requirements even in emergency operation.

6.7 RECOVERY

6.7.1 Summary of damage

Tables 6-3 and 6-4 show summaries of damage to structures and processing equipment, respectively.

6.7.2 Spare parts and cannibalization

The plant has a stock room with a good supply of the spare parts normally required in regular maintenance and service. If several machines of a similar type are damaged, parts from one may be cannibalized for use on another to initiate partial production. There are several production lines in the plant where this could be done.

6.7.3 Initiating emergency operation

Operation following low blast damage (0.0 psi to 2.5 psi)

The minimum requirements in this range to bring the plant into production will involve the paraffin building #4 where the roof shows cracking even below 2.5 psi. Any meters, gauges, or control equipment damaged would have to be repaired or replaced before liquid wax could be safely maintained and provided for production. Other areas may require sufficient cleaning of equipment to make sure they are safe to operate without further damage due to dust or pieces of glass.

Operation following medium blast damage (2.5 psi to 4.0 psi)

Minimum requirements to start production, without complete recovery, would involve considerably more work over this range. If a north or south blast were experienced, the west section of factory #1 would fail; otherwise it would stand up satisfactorily during this range. If failure took place, all equipment would have to be cleared of debris, cleaned, checked, repaired and prepared for operation. Some cannibalization could take place where machines are similar. The two printing presses are similar and some parts are interchangeable, but one is specially set up for pint cartons and the other is set up for quart cartons. Each machine is very specialized and cannot readily be changed over for production of the other size. However, by exchanging some parts, one machine might be placed in production and used while waiting for replacements and repairs on the other.

Six machines are used in making pint-size carton ends and three for quart sizes. These could certainly be cannibalized to prepare one machine for operation first, with others to follow as soon as repair can be carried out.

There are 5 box-folding units in operation and these could be cannibalized so as to place some machines in operation with exchange of parts. The machines damaged the most would be left until last.

Table 6-3 Summary of Damage to Structures at Waxed Carton Plant

Pressure psi	Bldg. #1 Factory	Bldg. #2 Ware-House	Bldg. #3 Truck Dock	Bldg. #4 Paraffin Storage	Bldg. #5 Train Shed	Bldg. #6 Boiler-House	Bldg. #7 Office	Bldg. #8 Ware-House	Bldg. #9 Truck Dock	Bldg. #10 Drum Storage
0.1	Glass Cracking	Glass Cracking	Glass Cracking			Glass Cracking	Glass Cracking	Glass Cracking	Glass Cracking	
0.5	Glazing Shattering	Glazing Shattering	Glazing Shattering			Glazing Shattering	Glazing Shattering	Glazing Shattering	Glazing Shattering	
1.0				Roof Cracks						Roof Cracks
2.0										
2.5	West-section fail/ N-S Blast	General Failure		Roof Collapse				South portion fail/ E-W blast		Roof Collapse
3.0			Moderate Damage	Walls Collapse			Roof Cracking		Moderate Damage	Walls Collapse
4.0	General Failure		Collapse	Frame Mod. Damage	General Failure			General Failure	Collapse	Frame Mod. Damage
5.0						Frame Mod. Damage	Frame Collapse			
6.0				Frame Collapse		Walls Collapse				Frame Collapse
7.0				Tanks-full Overturn		Frame Collapse				
8.0										

Table 6-4 Summary of Damage to Processing Equipment at Waxed Carton Plant

Structural	Critical Overpressure	Processing Equipment
Glass cracking	0.1	dust and fallout.
Fenestration collapse	0.5	glass and missile dam. to equip.
Paraffin building #4 roof collapse	1.0	instruments and controls dam.
Drum storage #10 cracking		package items damaged.
Factory bldg. #1 west section fails	2.5	carton forming & sealing equip. dam.
Warehouse bldg. #2 general failure		packaging & warehouse equip. dam.
Paraffin bldg. #4 roof collapse		piping and controls damaged.
Warehouse #8 south section fails		packaged material damaged.
Drum storage #10 roof collapse		paint mixing equip. damaged.
Truck dock #3 mod. damage	3.0	equipment damage.
Paraffin bldg. #4 walls collapse		piping and pumps damaged.
Office bldg. #7 roof cracking		debris and office equip. damaged.
Truck dock #9 mod. damage		debris and equipment damaged.
Drum storage #10 walls collapse		equipment badly damaged.
Factory bldg. #1 general failure	4.0	carton mach. dam. & demolished.
Truck dock #3 collapse		dock equipment damage.
Paraffin bldg. #4 frame mod. damage		pipe, tank fittings, controls dam.
Train shed #5 general failure		damage to loading equipment.
Warehouse #8 general failure		dam. to stock and handling equip.
Truck dock #9 collapse		damage to loading facilities.
Drum storage #10 frame mod. damage.		equipment dam. & demolished.
Boilerhouse #6 frame collapse	5.0	missile dam. to meters & controls.
Office #7 frame collapse		all equipment demolished.
Paraffin #4 frame collapse	6.0	tanks dam. piping & equip. demolished.
Boilerhouse #6 walls collapse		piping & boilers damaged.
Drum storage #10 frame collapse		all equipment demolished.
Paraffin storage #4 tanks overturn	0	tanks and equipment demolished.
Boilerhouse #6 frame collapse		all equipment demolished.

Normally, most of the repair work is performed in the plant's own machine shop, and under emergency conditions the shop could probably still do most of the work. The machine shop itself is, however, vulnerable to the effect of building failure and may receive some damage if building #1 should collapse completely, but this is not likely to happen over this range of blast pressures.

The waxing operation is carried out on one machine, and so there is no opportunity for cannibalization. It is a large covered unit containing a heating process on one side and cooling process on the other. The equipment inside is heavy and rugged; it may not be damaged, but the covering would need replacing before the unit could be placed in operation. One dangerous condition here is the gas heating system for maintaining the molten paraffin for dipping the cartons. This gas supply should be shut off to stop any burner flames.

Production could be initiated if one unit of each phase of operation could be prepared and all necessary effort should be made in this direction. This would include one print machine used only to place glue and cut to carton size, one end making machine, one carton forming unit, and the carton waxing unit. Production would be small but could be increased as fast as parts could be supplied and repairs carried out on other units.

Operation following high blast damage (4.0 psi to 7.0 psi)

Factory #1 will require a great deal of work to clean up around equipment and carry out repairs or cannibalization in order to obtain at least one line of process equipment for commencing operation in some minimum amount.

Paraffin storage building #4 will have to be sufficiently cleared to maintain and supply paraffin to the process. Special work will be required to remelting the paraffin in order to have it ready for pumping to the process equipment when production is ready.

The boilerhouse should be made ready as soon as possible, to provide heat for unloading tank cars of paraffin.

6.7.4 Shortcuts

Cartons could be made without printing but they will still need to have the glue placed on them by the printing machines. Otherwise, to make milk cartons and assure a leak-proof product it is necessary to form them, seal with glue, and wax as usual. Some identification of product for postattack use would undoubtedly be required, perhaps via rubber stamps and ink pads.

6.7.5 Utilities

Electric power

Electric power is essential to provide melted wax for the production line. The electric power is supplied by power companies and these lines would generally remain intact to near 4.0 psi. If damaged, however, they could be repaired in time to supply paraffin sooner than equipment would be ready for production.

If electric power is lost for more than 12 hours, most of the paraffin will be solidified. To bring it back to the molten state would take higher electric currents than ordinary operation requires, to supply the heat of fusion. This could be accomplished by means of welding machines placed on piping or wherever required to help.

Steam supply

The boilerhouse provides heat for the buildings and heat to melt paraffin in the railroad tank cars prior to unloading. Otherwise, it is not part of the process operations to any large extent. Gas flame is used to heat the cartons for gluing and for paraffin melting, so steam is not needed in these processes. During the cold months, heating would be very important to the comfort of workers. General checking and repairing would be necessary to repair damaged gauges, controls and equipment.

6.7.6 Repair required to resume normal operation

Low blast pressure range

A complete cleanup of dust, dirt and debris must precede cleaning of equipment and repairing missile damage. This cleanup and repair would be performed throughout the plant.

The roofs of paraffin building #4 and drum storage #10 should be checked for structural integrity, after which additional supports could be installed where required, provided they do not interfere with the equipment. Instruments and controls in the paraffin building will require repair and packaged items in drum storage will have to be restacked.

Medium blast pressure range

In addition to the repairs necessary in the low pressure range, a medium blast will add the following:

At 2.5 psi, the west section of factory #1 will have to be rebuilt and the equipment in this section will require extensive repair. The collapsed warehouse #2 will require rebuilding and all packaged material which was destroyed will have to be disposed of and that which survived would require restacking. The can assembly equipment will need rebuilding.

The collapsed roofs of the paraffin building #4 and the drum storage building #10 will require rebuilding, and the vertical cylindrical steel tanks in the paraffin building will require repair of the piping connections damaged by the roof collapse, and there would be general cleanup of all the spilled wax, as well as spilled and broken cans of paint, varnish and printers ink in drum storage. Piping running from a varnish receptacle to the machines which apply varnish at the can assembly should be repaired. Warehouse #8 will have to have the south portion of the building rebuilt and all stored cartons and cans inspected and restacked.

At 3.0 psi, the collapsed walls of paraffin building #4 and drum storage #10 will need rebuilding. Considerably more cleanup than that in the low range is required around the paraffin tanks. Empty paraffin tanks will need repair as will the attendant piping. The material stored in drum storage can be considered as totally lost.

The cracked office roof will need repair and additional support must be provided. Any wiring for overhead lighting will need inspection and the broken connections repaired. The truck loading docks will require minor repair.

High blast pressure range

Moderate frame damage at paraffin building #4 and drum storage #10 at 4.0 psi, will require inspection and realignment. The truck dock damage will require the clearing away of the debris and the docks rebuilt with new platform equalizers. The train shed and warehouse #8 will require extensive repairs to the structure.

At 5.0 psi, the boilerhouse frame will need straightening and the office building frame should be rebuilt. Equipment in the boilerhouse will need cleaning and repair. At 6.0 psi, the frames of paraffin tanks will require extensive repair or replacement due to buckling, and repiping will be required. The boilerhouse walls need rebuilding and instruments such as controls and gauges will have to be replaced. Steam lines will need replacing.

At an overpressure of 7.0 psi or greater, the boilerhouse frame and the paraffin building will collapse, resulting in the complete failure of the plant.

6.7.7 Substitutes

Before cartons were supplied in the present form, glass bottles and jars, as well as regular metal cans were used to package many food items. These could be substituted and used at any time the need arose. The substitutes, of course, would have to be manufactured elsewhere, because blast severe enough to put the carton manufacturing out of operation would probably have a similar effect on the beer can section of the facility. The beer cans tend to be superior to other food cans, in that they are designed to survive an appreciable internal pressure and are quite thoroughly enameled, hence could be widely substituted.

6.7.8 Increased production capability

The plant usually operates on two and three shifts per day through a five day week. A full, three shift day for seven days a week would increase production proportionately. This could be done provided enough trained personnel were available to operate and maintain the equipment.

6.7.9 Estimated man-days required for repair for each level of blast pressure

Repair estimates are found in the following charts. A recovery chart which summarizes graphically the repair effort to initiate emergency operation and to recover completely is found in figure 6-9.

WAXED CARTON PLANT

Low Blast Damage Range 0.0 to 2.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
0.1	glass cracking throughout plant	clean up dust and dirt	labor	5	10	50
0.5	glass failure complete	pick up glass and replace	labor	30	10	300
1.0	paraffin bldg. #4 roof cracking	clean and repair	tradesmen labor	10	10	100
	roof cracks at drum storage #10	clean and repair	tradesmen labor	10	10	100
			Structural			550
	PROCESS					
0.1	glass windows start cracking	check fallout some dust and glass to pick up around equip.	labor	5	10	50
0.5	glass failure complete	clean and check all equipment repair missile damage	labor technicians	30	10	300
1.0	paraffin bldg. #4 roof cracking	check all instruments and controls - clean repair - check operation	labor technicians	10	10	100
	roof cracks at warehouse material scattered	pick up & re-stack packaged items	labor	5	10	50
			Process			500
			Structural			550
		Total Man-Days for Low Range				1,050

WAXED CARTON PLANT

Low Blast Damage Range 0.0 to 2.5 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
	clean around equipment so repair can be safely performed			10	10	100
	Process					
	clean, check & repair all equipment for missile damage			10	10	100
	clean and repair instruments and controls at paraffin building #4			2	10	20
		Total Man-Days for Low Range				220

WAXED CARTON PLANT

Medium Blast Damage Range 2.5 to 4.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
2.5	factory #1 west section fails/NS blast	clean up repair and rebuild	labor tradesmen engineer	50	30	1500
	warehouse #2 general failure	clean up-repair and rebuild	labor tradesmen engineer	50	30	1500
	paraffin #4 roof collapse	rebuild	labor tradesmen	5	30	150
	warehouse #8 south portion fails/EW blast	clean up repair and rebuild	labor tradesmen engineer	50	30	1500
	drum storage #10 roof collapse	clean up rebuild	labor tradesmen	4	25	100
3.0	truck dock #3 moderate damage	clean up check repair	labor tradesmen	5	30	150
	paraffin #4 walls collapse	clean up rebuild	labor tradesmen	10	30	300
	office #7 roof cracking	clean up repair	labor tradesmen	15	30	450
	truck dock #9 moderate damage	clean up repair	labor tradesmen	5	30	150
	drum storage #10 walls collapse	clean up repair	labor tradesmen	8	25	200
			Structural			6,000

WAXED CARTON PLANT

Medium Blast Damage Range 2.5 to 4.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS					
2.5	factory #1 west section fails/NS blast	clean up equip. overhaul & repair	labor technicians	30	30	900
	warehouse #2 general failure	clean up equip. overhaul and repair	labor technicians	20	30	600
	paraffin #4 roof collapse	clean - check repair or replace equip.	labor tradesmen	2	30	60
	warehouse #8-south portion fails/EWblast	clean up	labor	5	30	150
	drum storage #10 roof collapse	clean up	labor	1	30	30
3.0	truck dock #3 moderate damage	clean up dock equipment	labor	1	30	30
	paraffin #4 walls collapse	clean and check repair or replace equip.	labor tradesmen	2	30	60
	office #7 roof cracking	non	non			
	truck dock #9 moderate damage	clean up dock and equip.	labor	1	30	30
	drum storage #10 walls collapse	clean up	labor	1	30	30
			Process			1,890
			Structural			6,000
		Total for	2.5 psi to 4.0 psi			7,890
		Total for	Low Range			1,050
		Total for	Medium Range			8,940

WAXED CARTON PLANT

Medium Blast Damage Range 2.5 to 4.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
2.5	clean up around machinery at factory bldg. #1			20	25	500
	clean up debris at paraffin wax bldg. #4			4	25	100
	Process					
2.5	clean up and repair machinery & equipment at factory bldg. #1			18	25	450
	clean, check & repair piping & controls			2	25	50
		Total for 2.5 psi to 4.0 psi				1,100
		Total for Low Range				220
		Total Man-Days for Medium Range				1,320

WAXED CARTON PLANT

High Blast Damage Range 4.0 to 7.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
4.0	factory #1 general failure	clean up rebuild	labor tradesmen engineer	20	60	1200
	truck dock #3 collapse	clean up rebuild	labor tradesmen	5	60	300
	paraffin storage #14 frame-moderate damage	clean up rebuild	labor tradesmen	5	60	300
	train shed #5 and warehouse #8 general failure	clean up rebuild	labor tradesmen engineer	25	60	1500
	truck dock #9 collapse	clean up rebuild	labor tradesmen	5	60	300
	drum storage #10 frame - moderate damage	clean up repair	labor tradesmen	5	60	300
5.0	boilerhouse #6 frame - moderate damage	clean up repair	labor tradesmen engineer	5	60	300
	office #7 frame collapse	clean up rebuild	labor tradesmen	25	60	1500
6.0	paraffin storage #4 frame collapse	clean up rebuild	labor tradesmen	5	60	300
	boilerhouse #6 walls collapse	clean up rebuild	labor tradesmen	10	60	600
	drum storage #10 frame collapse	clean up rebuild	labor tradesmen	1	60	60
			Structural			6,660
	Note: At 7.0 psi or above it is no longer economical to repair plant.					
7.0	paraffin storage #4 overturns	rebuild				
	boilerhouse #6 frame collapses	rebuild				

WAXED CARTON PLANT

High Blast Damage Range 4.0 to 7.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS					
4.0	factory #1 general failure	clean equipment overhaul and repair	labor tradesmen technicians engineer	20	60	1200
	truck dock #3 collapse	clean & repair dock equip.	labor	2	60	120
	paraffin storage #4 frame moderate damage	check & repair equip. remelt paraffin	labor	1	60	60
	train shed #5 & warehouse #8 general failure	clean and re-pair equip.	labor	2	60	120
	truck dock #9 collapse	clean & repair dock equip.	labor	1	60	60
	drum storage #10 frame mod. damage	clean up equip.	labor	1	60	60
5.0	boilerhouse #6 frame moderate damage	clean equip. check & repair replace parts	labor tradesmen technicians engineers	10	60	600
6.0	paraffin storage #4 frame collapse	complete over-haul - replace & repair equip. and piping	labor tradesmen	5	60	300
	boilerhouse #6 walls collapse	check for more extensive dam.	labor tradesmen technicians engineers	10	60	600
	drum storage #10 frame collapse	clean up	labor	1	60	60
			Process			3,180
			Structural			6,660
		Total for	4.0 psi to 7.0 psi			9,840
		Total for	Medium Range			8,940
		Total for	High Range			18,780
10.0	paraffin storage #4 overturns boilerhouse #6 frame collapses					

WAXED CARTON PLANT

High Blast Damage Range 4.0 to 7.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
4.0	clean up debris at factory building #1 and paraffin storage #4			50	30	1,500
5.0	clean up debris at boilerhouse			10	30	300
	Process					
4.0	repair & cannibalize equipment to get one processing line in operation at factory bldg. #1			10	30	300
5.0	check & repair damage to paraffin supply equip.			1	30	30
	clean, check & repair damage to equipment at boilerhouse #6			10	30	300
6.0	repair damage in addition to that incurred at 5.0 psi			3	30	90
	repair & replace equipment at boilerhouse #6 to provide heat for unloading paraffin from tank cars			10	30	300
		Total for 4.0 psi to 7.0 psi				2,820
		Total for Medium Range				1,320
		Total Man-Days for High Range				4,140

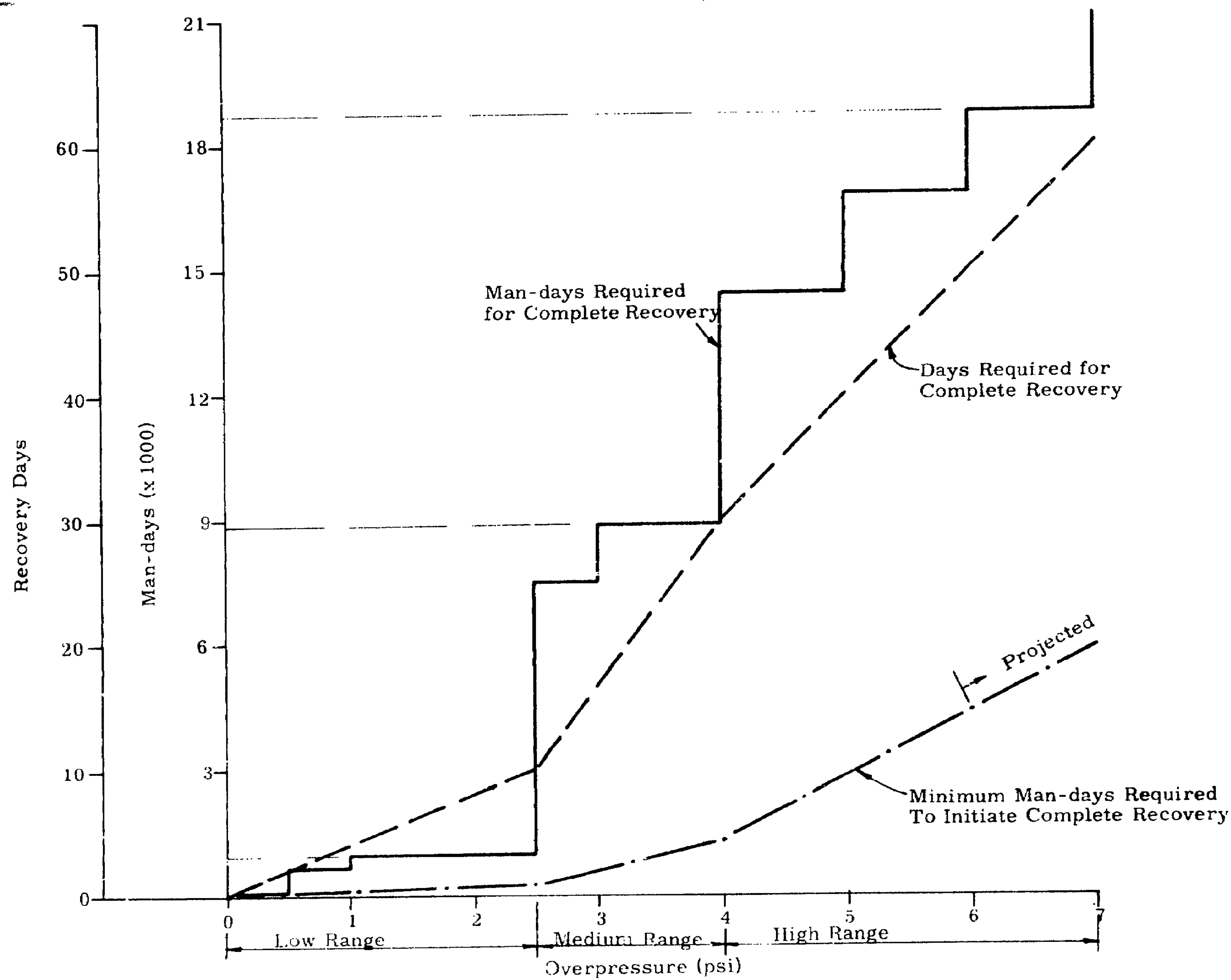


Figure 6-9 Recovery Chart - Waxed Carton Plant

6.8 CONCLUSIONS

Two representative plants were visited in conjunction with the container industry study: a can plant in Maine and a carton plant in Massachusetts. In terms of construction, the plants proved to be quite different; the can plant, built in 1920, exhibited the high blast resistance generally associated with older construction, while the modern carton plant has the high vulnerability typical of recent, more sophisticated construction. Both types of containers are essential to the packaging of food, and would play important roles in any postattack era. Cans, of course, lend themselves to the indefinite, unrefrigerated preservation of almost all perishable foods, while cartons find their chief application in one important item, fresh milk. If the carton industry were destroyed, it would prove most difficult to move milk from the dairies to consumers.

Damage ranges (carton plant): low 0.0-2.5; medium 2.5-4.0; high 4.0-7.0; (can plant) low 0.0-3.0; medium 3.0-7.0; high 7.0-12.0. The industry is not considered to be particularly vulnerable because of its wide dispersion throughout the United States. However, the use of the containers would be curtailed if transportation facilities were unavailable as a result of the attack. There are no shutdown problems, and shortcuts include extensive, cannibalization, interchangeability of glass containers, cans, and perhaps the substitution of plastic bags and paper cartons in certain instances.

A comparison of the two recovery charts gives some measure of the range of applicability of the studies to the entire industry. The low damage ranges coincide reasonably well, but a wide difference occurs between the medium ranges (2.5-4.0 vs. 3.0-7.0) and the high (4.0-7.0 vs. 7.0-12.0) of the can and carton plants. This is due primarily to the greater structural vulnerability of the newer plant. The repair times, conversely, are much greater for the older plant, which tends to balance out somewhat its higher blast resistance over the medium range. The lower repair time reflects the greater simplicity of construction and hence reconstruction at the newer plant.

7. EDIBLE FATS AND OILS INDUSTRY

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7. EDIBLE FATS AND OILS INDUSTRY

7.1 A REVIEW OF THE INDUSTRY

7.1.1 General

Edible fats and oils, in one form or another, supply 20.3% of the food energy requirements of the United States population. The edible vegetable oils are obtained from soybean, cottonseed, peanut, corn, safflower, palm, coconut, and olives. The animal fats are lard and tallow. The end products are primarily salad oil, margarine and various cooking fats and oils.

There is a growing surplus of edible fats and oils. This glut stems from two main causes: a change in dietary habits, and the inroads of synthetics and petroleum oils.

In 1961, the following quantities of fats and oils were used in the United States, in millions of pounds.[2]

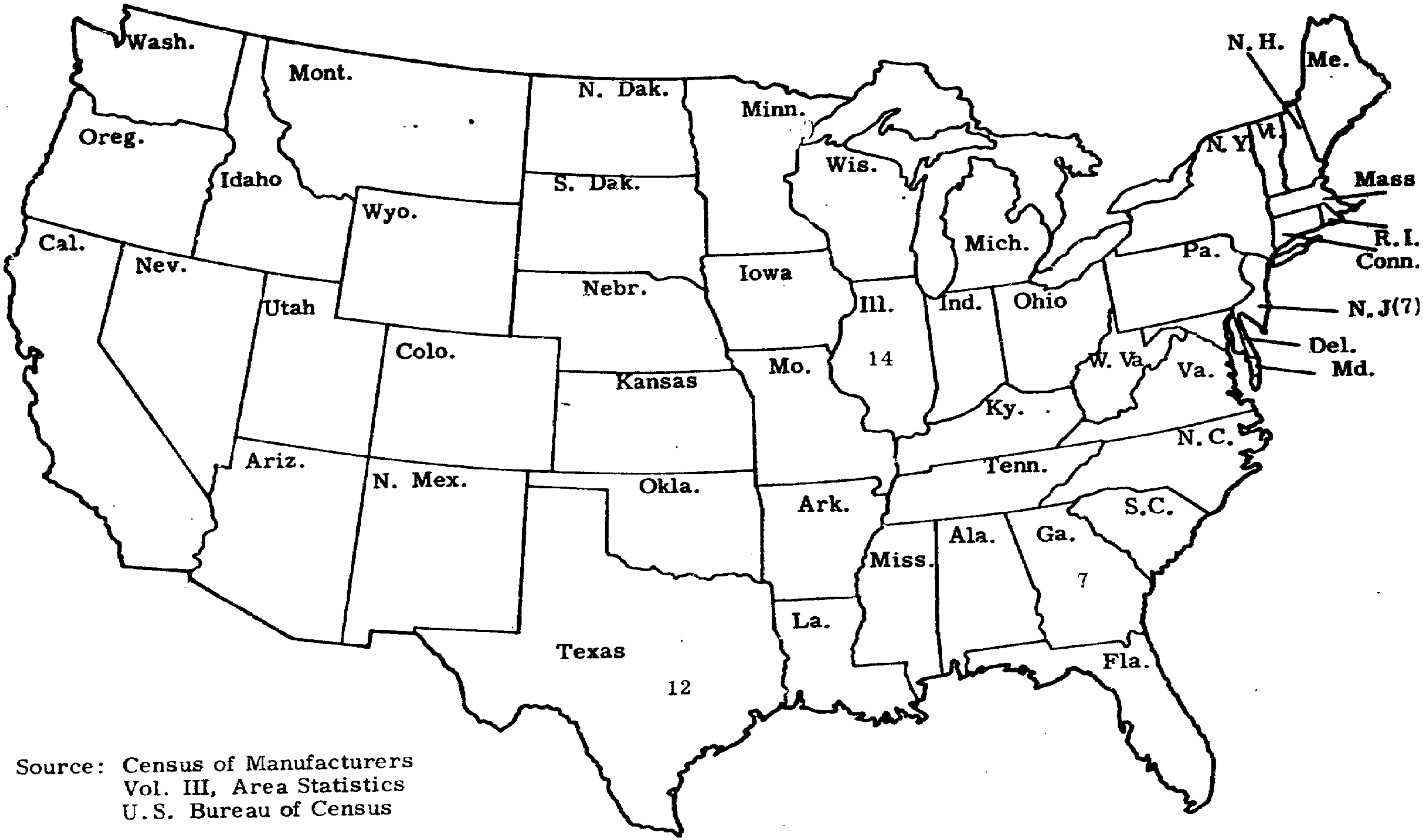
Animal Fats and Oils	
Tallow, edible	348
Lard, including rendered pork fat	530
Vegetable Oils	
Domestic	355
Cottonseed	1158
Soybean	36
Foreign	26

Domestic use of soybean oil has increased 50% in the past ten years. Its use is primarily in salad oil, shortening, and margarine. Cottonseed oil and corn oil can be used interchangeably with soybean oil in these products.

Cattle feed is an important byproduct of cottonseed oil, and is made from the seeds after the oil is pressed out of them. The increasing demand for meat has increased the demand and production of feeds, and along with it an increased quantity of oil.

7.1.2 Geographical locations

Edible fats and oils refining plants are concentrated in four states: New Jersey, Illinois, Texas and Georgia. Figure 7-1 shows the distribution of these plants which produce shortening, margarine and cooking oils.



Source: Census of Manufacturers
Vol. III, Area Statistics
U.S. Bureau of Census

Figure 7-1 Distribution of Refining Plants Producing Shortening and Cooking Oils, by States, 1958

7.1.3 Sources of supply

Plants producing crude soybean and cottonseed oils are widely distributed, with the heaviest concentration in the Southeast and Midwestern states, as shown in figure 7-2. Figures 7-3 and 7-4 show the distribution of soybean and cottonseed oil plants, respectively. They manufacture these crude oils for shipment to refining plants such as the one analyzed in this report.

7.1.4 Transportation

Two-thirds of the raw material (crude oils) brought into the plant arrive by railroad, and the remainder arrives by truck. The finished, refined products are shipped out with approximately equal amounts in bulk and packaged form. Of these, 80% of the liquid and 95% of packaged products are shipped by truck, and the remainder is shipped by rail.

7.1.5 Trends

Recent trends in edible oils have followed some of those generally applicable to the food industry, particularly in the development of a much greater variety of comparatively new products, such as polyunsaturated corn and safflower oils. The increase in varieties of products, most of which could serve equally well in an emergency, tends to increase somewhat the stocks available in homes and retail levels, and this would prove to be a postattack asset.

A much stronger trend, which could counteract that previously mentioned, is the disappearance of packaged shortening as a retail product, and its replacement by packaged mixes, containing all the ingredients necessary to produce rolls and cakes. The postattack effect of this has both favorable and unfavorable aspects; probably generally favorable, however, in that the problem of gathering a large variety of different ingredients for home baking would be eliminated.

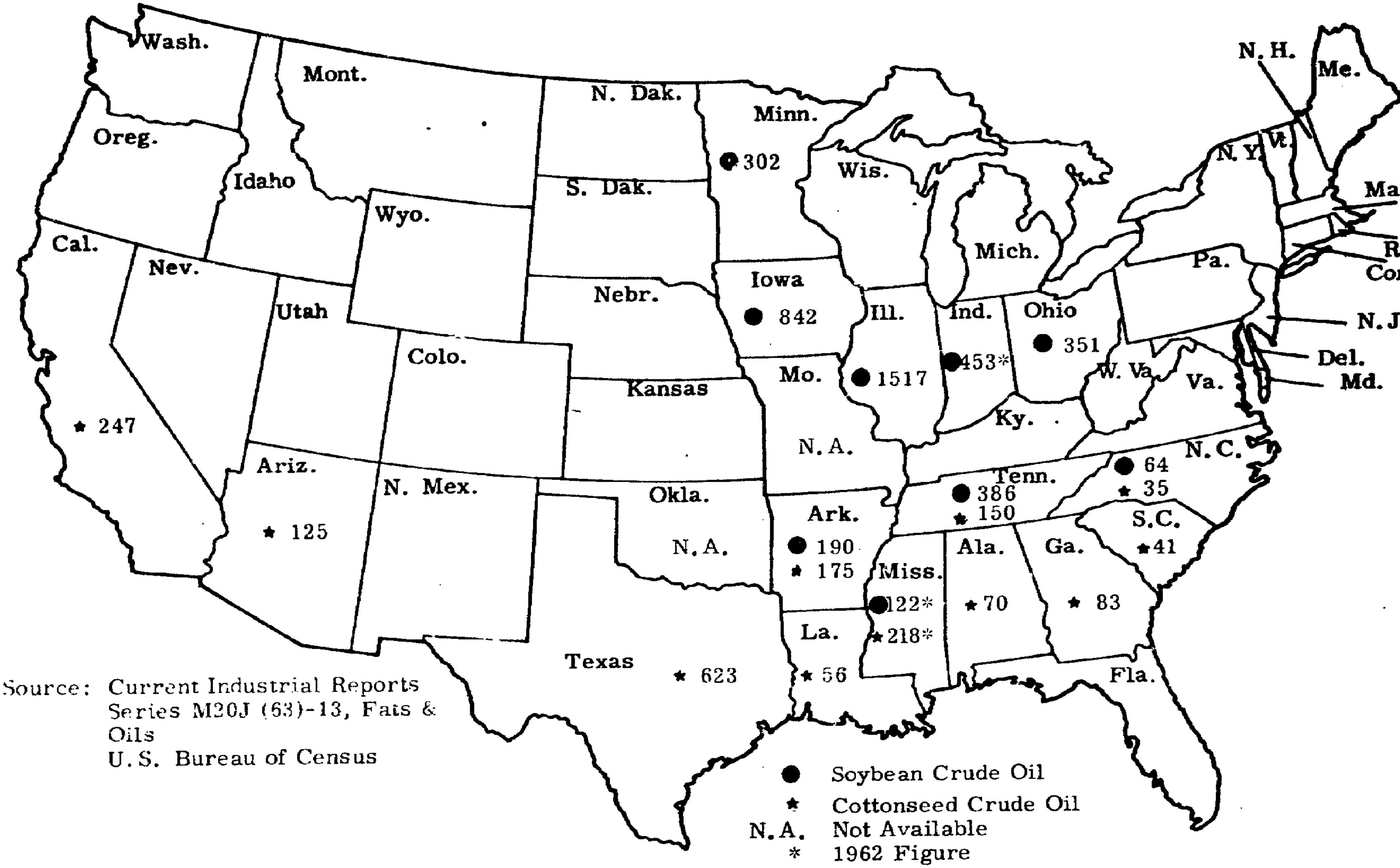
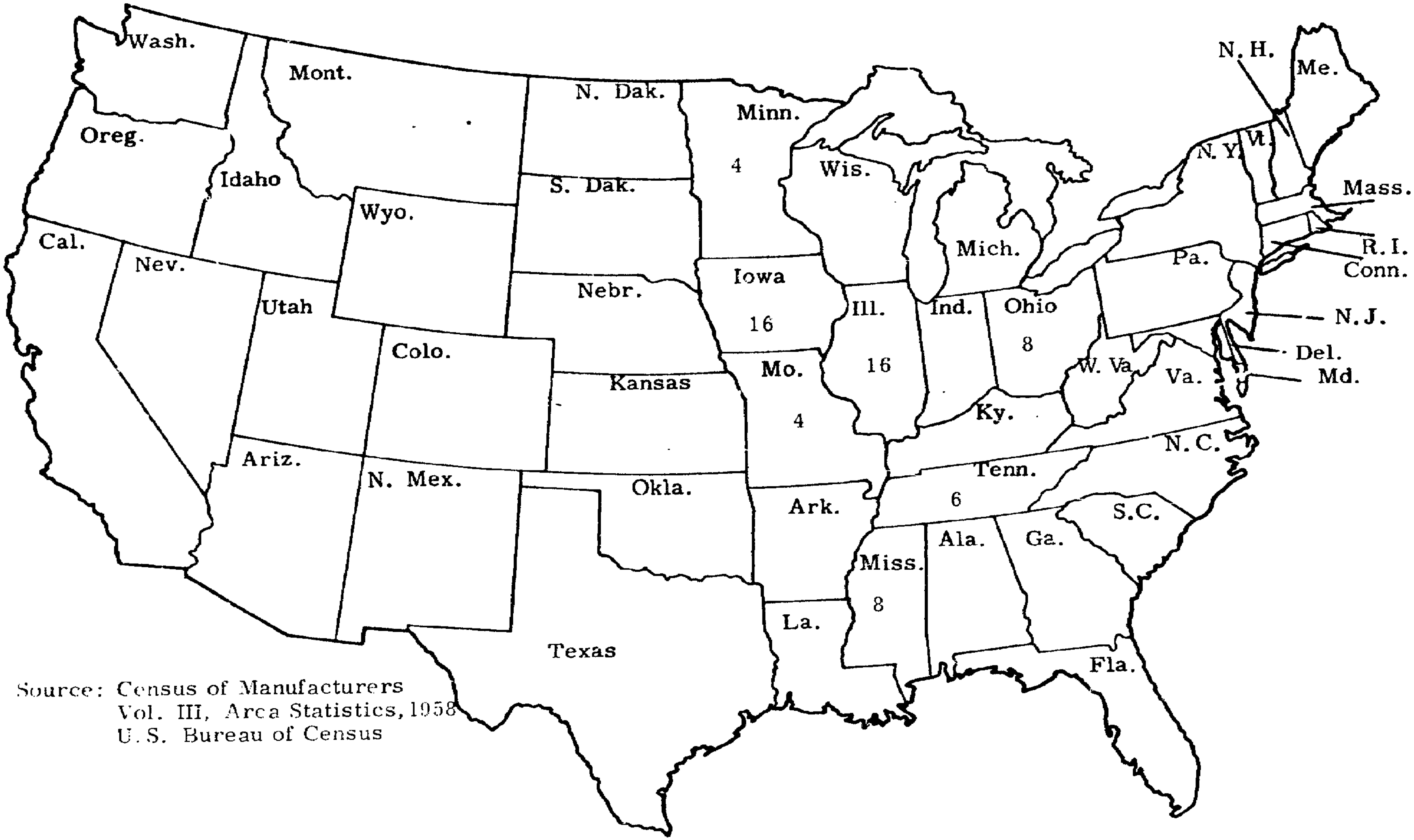
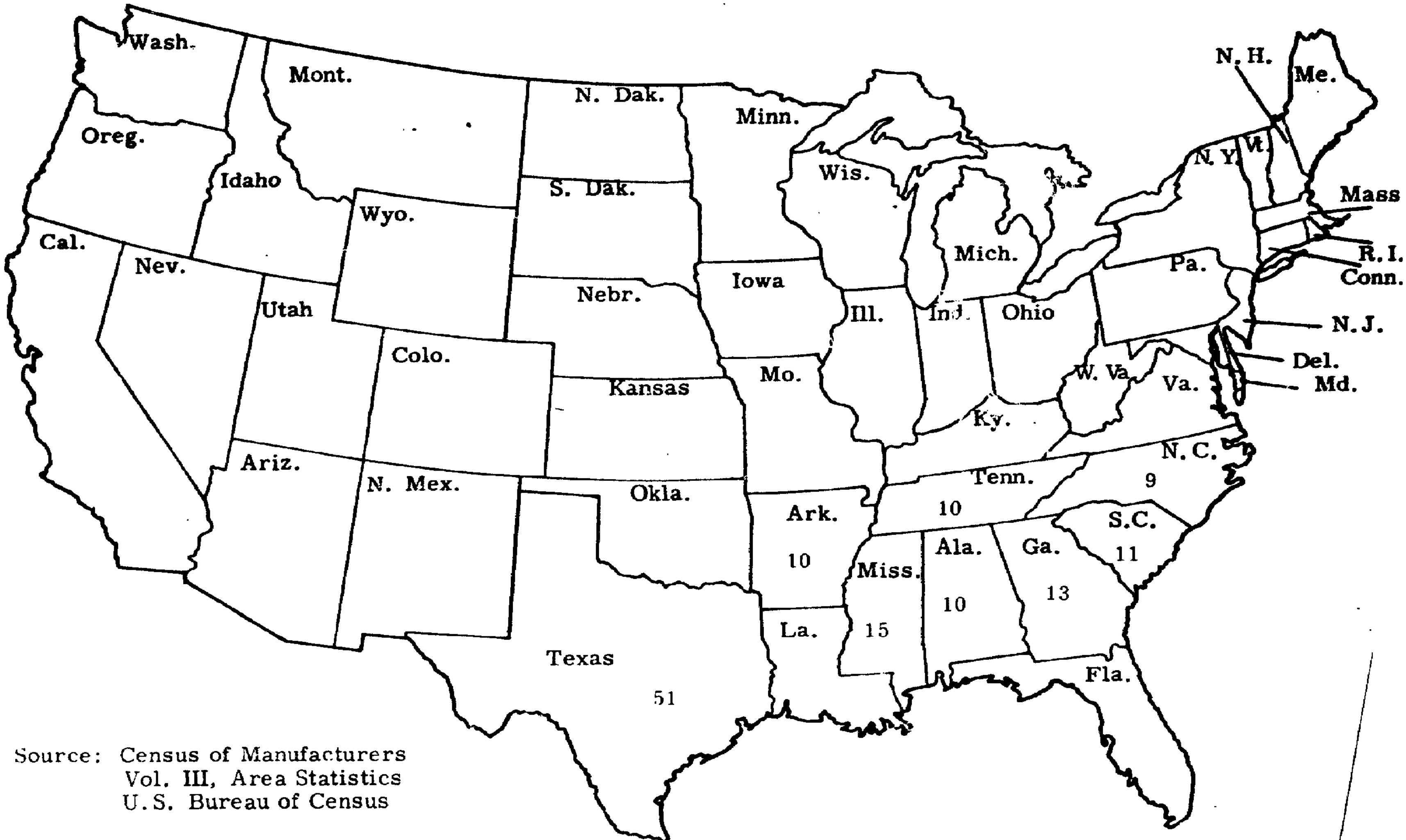


Figure 7-2 Production of Crude Oil from Soybean and Cottonseed by States, 1963



Source: Census of Manufacturers
Vol. III, Area Statistics, 1958
U.S. Bureau of Census

Figure 7-3 Distribution of Plants Producing Soybean Oil, by States, 1958



Source: Census of Manufacturers
Vol. III, Area Statistics
U.S. Bureau of Census

Figure 7-4 Distribution of Plants Producing Cottonseed Oil by States, 1958

7.2 EDIBLE OILS PROCESSING PLANT

7.2.1 General description

Edible oil refining is basically a chemical process in which oils from various parts of the United States and from overseas are refined by chemical manufacturing techniques. The basic chemicals involved are either monoglycerides, diglycerides or triglycerides, depending on the number of radicals of the various fatty acids attached to the basic glycerine molecule.

The basic domestic raw materials include soya oil, peanut oil, cotton oil, corn oil, and safflower oil; palm oil and cocoanut oil are imported from Latin America and overseas. The meat packers supply lard from pork, and tallow from cattle, to be used in the manufacturing process.

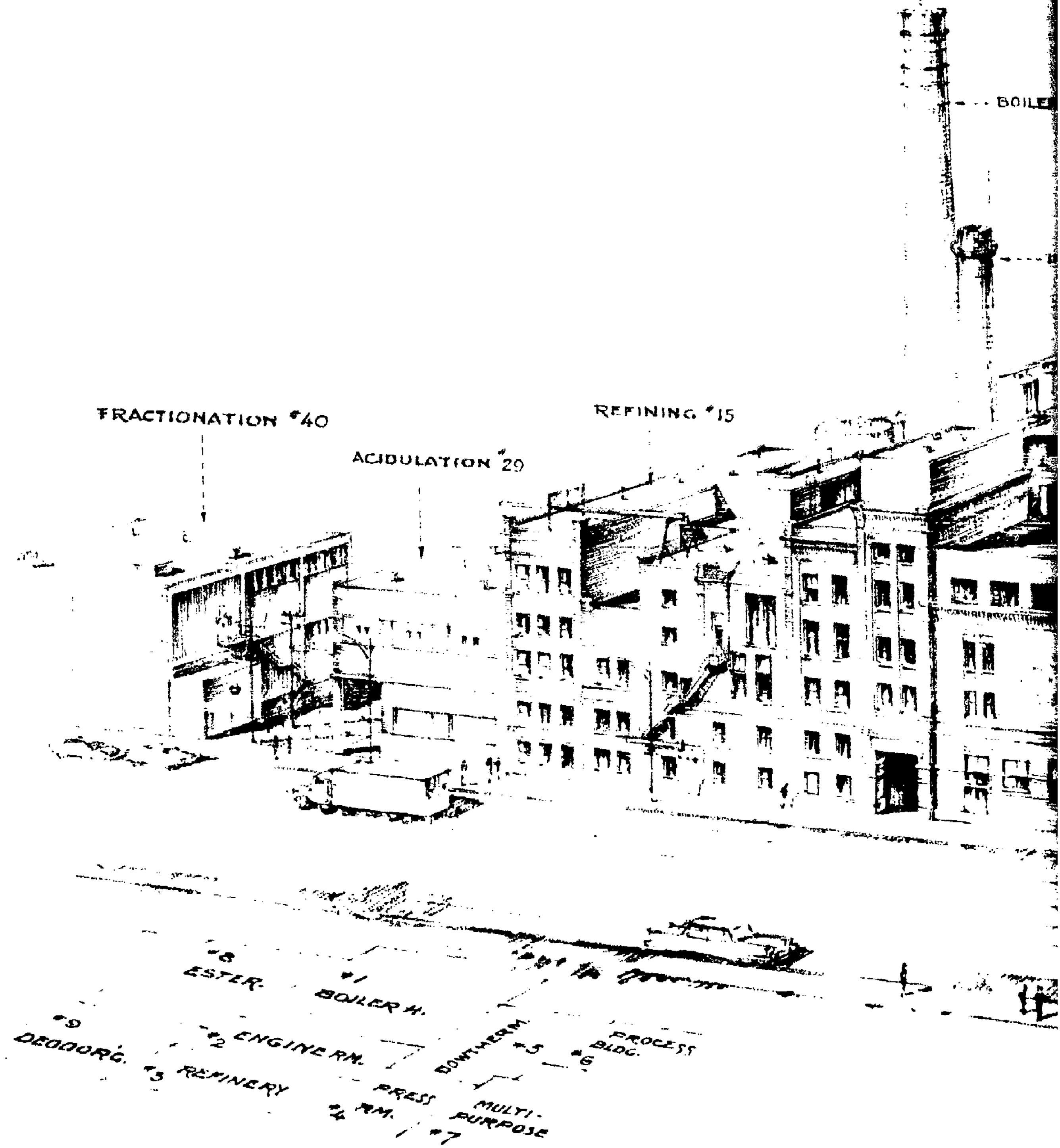
The plant studied, Durkee's Famous Foods, is old and is located in an industrial area of Chicago. Having been converted from a brewery, it does not lend itself to logical or continuous flow of materials, and there is a certain amount of backtracking and crisscrossing of product as it is moved from one process to the next, sometimes spending time in storage in between. But the plant is one of the most versatile in the industry, and operates essentially by a series of batch processes. The more efficient continuous flow process plants generally are much more specialized and not capable of producing the variety of products.

Most operations are manually controlled, at least in the process areas. The hydrogen plant and the fractionation plant are the most modern, and these have more instrumentation and automatic control of operation. The oil is in liquid form and is generally moved through pipes by a combination of pumping and gravity feed.

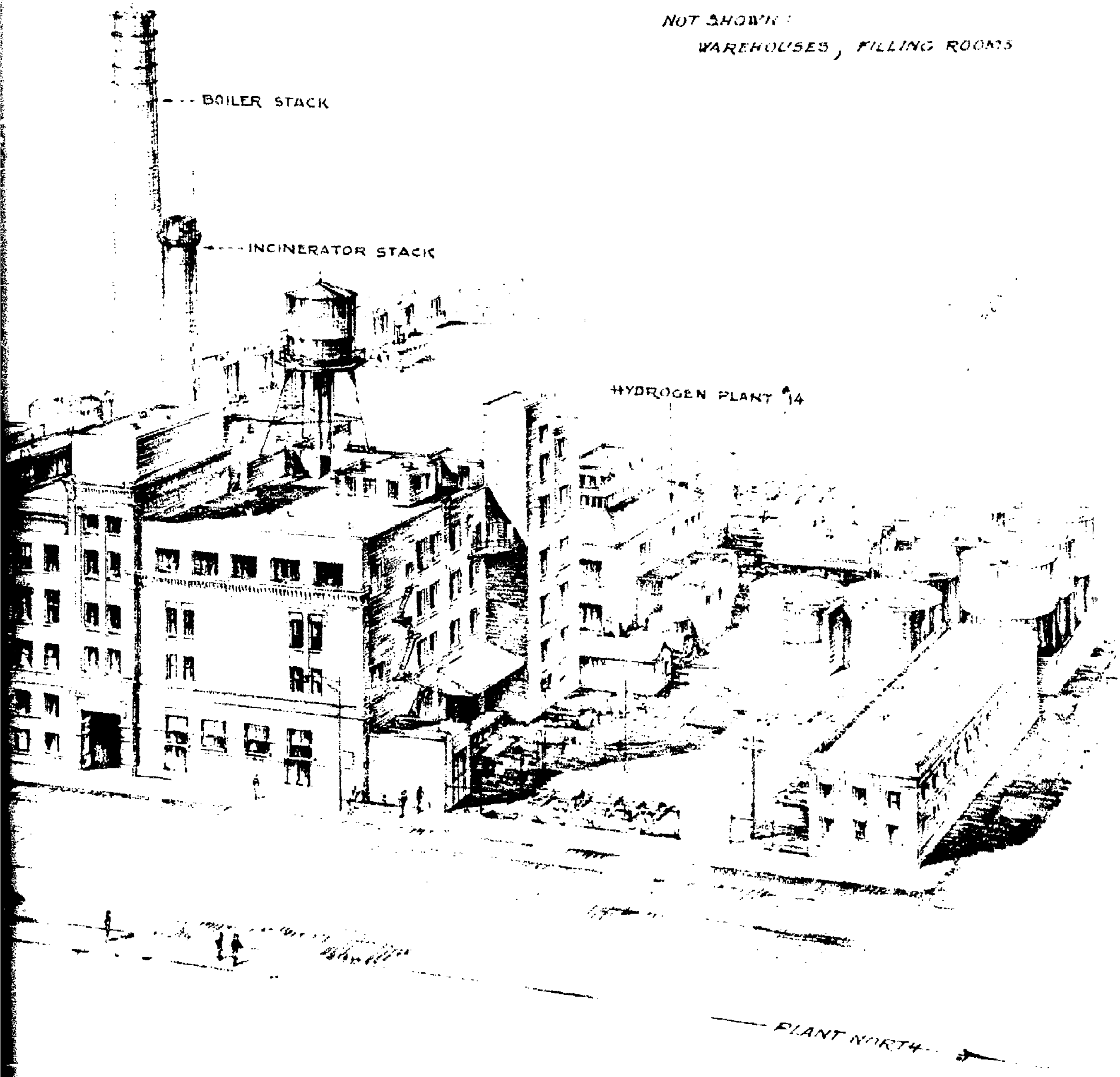
The equipment consists of tanks, piping, pumps, electric motors for the agitators, and the filter presses. The tanks are both open and closed, with the agitator motor drives located above them. The filter presses are constructed in heavy cast iron sections which are bolted together with the cotton filter material in between. The centers of the castings are open and allow the oil to be forced through the cotton filters by piston pumps. The entire assembly is enclosed to prevent leakage.

The plant is, in reality, a group of twelve buildings, which are horizontally contiguous (several share party walls), and are interdependent to a degree that group reaction to nuclear pulses is a more realistic basis for analysis than individual reaction.

The boilerhouse, acidulation building, stacks, water tower and coal handling equipment, although located within the above group will be discussed separately because of their basic structural differences. Individual attention will be given to the hydrogen production building, the solvent extraction building, and the yard tank facilities. These buildings are illustrated in figure 7-5 and shown in plot plan in figure 7-6.


FRACTIONATION #40
ACIDULATION #29
REFINING #15
#8 ESTER.
#1 BOILER H.
#9 DEODORG.
#2 ENGINE RM.
#3 REFINERY
DOWTHERM
#5
#6 PROCESS BLDG.
PRESS #4 RM.
MULTI-PURPOSE #7

Edible-Oils



Edible-Oils Processing Plant

Figure 7-5

LEGEND

1. Boiler House
2. Engine Room & Stills Building
3. Refinery
4. Press Room Building
5. Dowtherm Boiler House
6. Process Building
7. Multipurpose Building
8. Esterification Building
9. Deodorizing Building
14. Hydrogen Gas Plant
15. Refining Building
17. Deep Well Pump House
29. Acidulation Building
40. Fractionation Plant

A. Boiler Stack
B. Incinerator Stack
C. Water Storage Tank
D. Coal Elevator

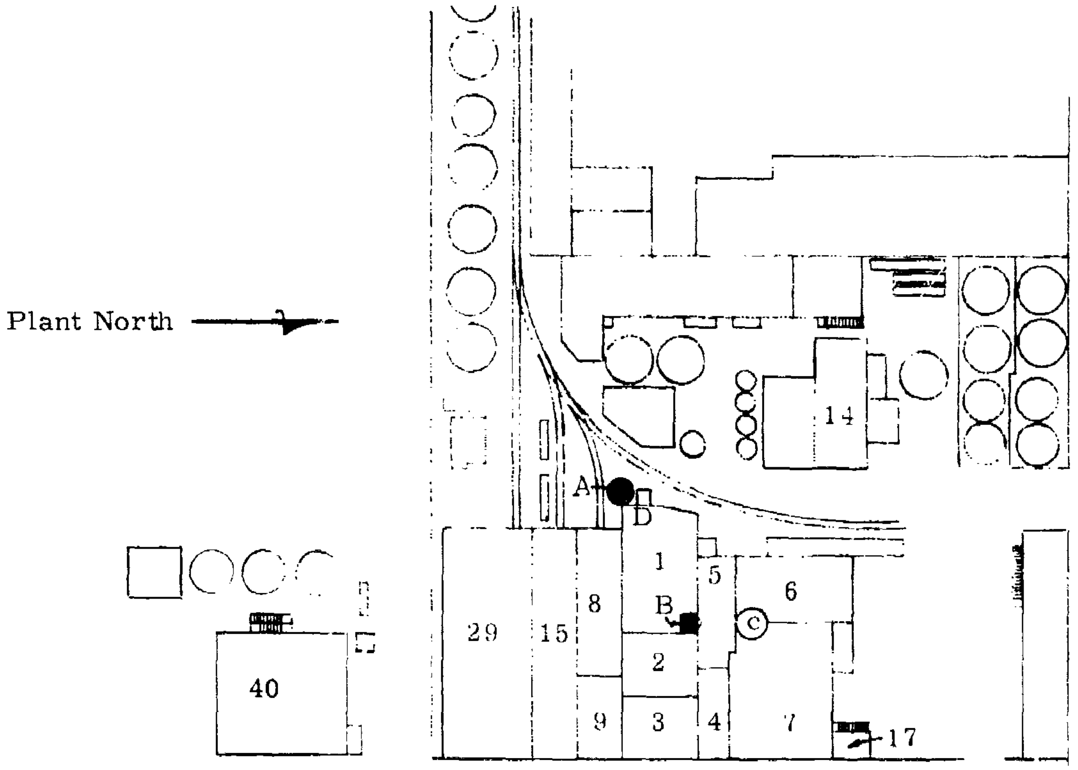


Figure 7-6 Plot Plan of Edible-Oils Plant

Principal process group

The buildings comprising this group are numbers 1 through 9, 15, 17, and 29.

Buildings 2 through 9 and 15 vary in size and in type of construction. Roofs are constructed of a variety of materials such as corrugated transite, concrete slab, hollow tile and wood sheathing. In some cases combinations of these materials are in evidence on the same roof. Beams supporting the roofs range in material from wood to steel and concrete. All exterior walls are constructed of brick masonry varying in thickness from 12 to 14 inches and contain window areas ranging from none to 30%.

Building #17 is a one-story masonry building which formerly housed a deep-well pump and is no longer in use, although its composition roof supports the incoming electric power ducts.

Boilerhouse (bldg. #1) and stacks

The building measuring 43' x 68' x 40' is a brick-walled structure framed with steel beams and columns and covered by a roof of wood sheathing on wood purlins. Four coal-fired boilers, a large catenary coal bunker and an incinerator are housed within. Customarily one boiler is operating with three standing by.

The east and west walls of the boilerhouse have no windows; the north wall is windowed above 30 feet and the west wall has an extensive window area. The brick boiler stack, located on the west side of the boilerhouse, is 175 feet tall and is set on a 40-foot-high octagonal base which measures 13 feet across each side and is constructed integrally with the wall.

In the northeast corner of the boilerhouse is another brick stack which vents the incinerator. This stack, whose diameter measures 9 feet at the roof level, is cantilevered for 90 feet above the roof and is effectively braced against lateral movement at the roof level.

Water storage tower

A 30,000-gallon water tower rises 30 feet above the roof at the junction of buildings number 6 and 7. The legs of the tripod frame are mounted on 12-feet high brick walls which are extensions of party walls in the building. The 19' x 17' diameter cylindrical tank is constructed of vertical wood staves held together with closely spaced tension hoops.

Coal handling equipment

Coal is supplied to the bunker by a continuous vertical chain bucket. The buckets are filled from a pit below the level of a spur track, raised to a point about 20 feet above the west wall of the boilerhouse passing through a rectangular steel-plate vertical bucket housing and then tripped into a bunker chute. The tripper house, also enclosed by steel plate, is supported on top of and by the vertical bucket shaft. The proportions of the tripper housing are such that wind loads would concentrate their effects upon the top end of the cantilever shaft, stressing the shaft in bending at the roof level.

No bucket shaft details were ava[illegible]ble; however, coal handling systems as old as this one are usually much weaker than when new because of the inevitable corrosiveness of H_2SO_4 and other acids formed by coal impurities and moisture.

Acidulation building (bldg. #29)

Although the acidulation building actually is a member of the principal process group by virtue of its location and service, it is treated separately here because its more modern architecture becomes a factor affecting its response to blast loading.

The building is rectangular measuring 51' x 125' x 40' with 12" masonry walls on three sides; the north side being a party wall of building No. 15. The floors, roof, beams and columns are made of reinforced concrete, the latter having a diameter of 18 inches.

Glass block windows occupy about 30% of the east wall; less than 10% apertures interrupt the south wall and west wall.

Fractionation plant (bldg. #40)

Sometimes called the solvent extraction building, this two-story structure is one of the more recently erected at the plant. The plan dimensions are 75' x 75' x 35' high. None of its walls is shared by other buildings. Bay spacings are 25 feet each way. The east wall is composed of 8" block and 4" brick, with no apertures of any kind. One of three north panels is of the same construction except that it contains a row of sash under the roof line. The remaining wall areas in general are made up of insulated corrugated asbestos with a row of windows near the roof line. Roof, floors, beams and columns are of reinforced concrete, the latter having a cross-section 18 inches square.

Some explosion danger is inherent in the operation, dictating the design of the corrugated siding as blowout panels. For nuclear blasts, blowin panels would be required, for which these are admirably suited.

Hydrogen gas plant (bldg. #14)

The hydrogen gas required in the fats hardening process is generated locally in a mill building 36' x 70' x 36' high to the peak of the monitor. The walls of this building consist of 12" thick brick masonry and glazed with standard steel sash. The east and west walls contain about 30% glazed sash; the four-bay north wall has three bays which are 80% apertured and one bay which is 12" solid brick. The south wall which is a party wall with another building is solid 12" brick except for one connecting door.

Steel roof trusses on steel columns constitute the framing of this building with a louvered monitor extending the entire length of the building and centered on the truss ridge line. The roof material is corrugated transite supported on steel purlins.

Exterior tanks

A wide variety of tanks is used in the typical oil processing plant. This plant has more than 30 crude edible oil storage tanks in the plant yard with a total storage capacity of several million gallons. Individual tank capacities vary from 10,000 gallons to more than 150,000 gallons. Other yard vessels are used for low-pressure hydrogen collection, high-pressure hydrogen storage, caustic soda and sulfuric acid supplies.

7.2.2 Operation

Raw materials are brought in by trucks, tank cars and ships and are stored in tanks pending refining. Hard fats require melting before removing them from the trucks or the tank cars and placing them in the storage tanks. All of the inbound crudes are weighed. Storage capacity, in 1 million pound tanks, is now approximately 17 million pounds, and it is expected to be increased. Figure 7-7, flow chart, illustrates diagrammatically the processing system.

The refining process is the first step. Caustic soda, sodium silicate, sodium chloride and water remove free fatty acids, meal, gums and phosphatides. The heavier stock, which is separated by a gravity separator, is transferred to tanks as byproduct soapstock and later packed in drums, or put into tank cars or tankwagons for shipment to alkyds, soapers and distillers. The main product, which is lighter, is then vacuum dried at 160° to 180°F.

The bleaching process includes this vacuum drying, and the addition of fuller's earth and carbon in order to bleach. All traces of bleaching materials are removed in a filter press before the next process, by forcing the oil under pressure through cotton fabric. Depending on the end product desired, various other processes may follow.

Hardening processes- salad oils generally require that "hardness" be removed. It is possible to remove "hardness", or the high-temperature melting point oils, by means of filtration. Alternately, if a hard fat or a solid fat is desired, hydrogenation or interesterification processes follow.

Hydrogenation is a chemical process using a nickel catalyst which involves the addition of extra hydrogen to the various fatty acid radicals, producing an increase in the saturation of the given oil. The process involves large tanks containing the nickel catalyst.

Interesterification is a catalytic chemical process, involving rearrangement of the atoms within and between the fatty acid radicals, to convert one type of oil to another.

Deodorizing is a steam distillation of the product, under partial vacuum, to remove the lighter components.

Packaging is done in various forms. The plastics are fats which are allowed to solidify with large quantities of dissolved air. Flakes and powders are other forms of the solids. Shipment is made in bulk form in tank cars or wagons, in drums or in smaller packages.

The bulk of the plant output is shipped to wholesale users, i.e. large bakeries, a margarine plant, and the manufacturers of retail prepared mixes.

Hydrogen is manufactured separately in building #14, the hydrogen plant, from methane, i.e., from natural gas, which is piped from Texas and other gas fields. In the hydrogen plant, catalytic reaction involving monoethanolamine and nickel, steam (water) and methane combine to produce hydrogen, carbon monoxide, and carbon dioxide. Carbon dioxide is removed from the bottom of a cooling tank and vented outside; the lighter hydrogen is separated out at the top. The hydrogen compressors are capable of running at a maximum rate of approximately 22,000 cubic feet per hour. Storage of hydrogen consisting of 198,000 cubic ft., is in outside tanks at approximately 150 pounds per square inch, over water with a surge tank nearby for convenience. The water used in the storage of hydrogen is heated by steam in the winter to keep it from freezing.

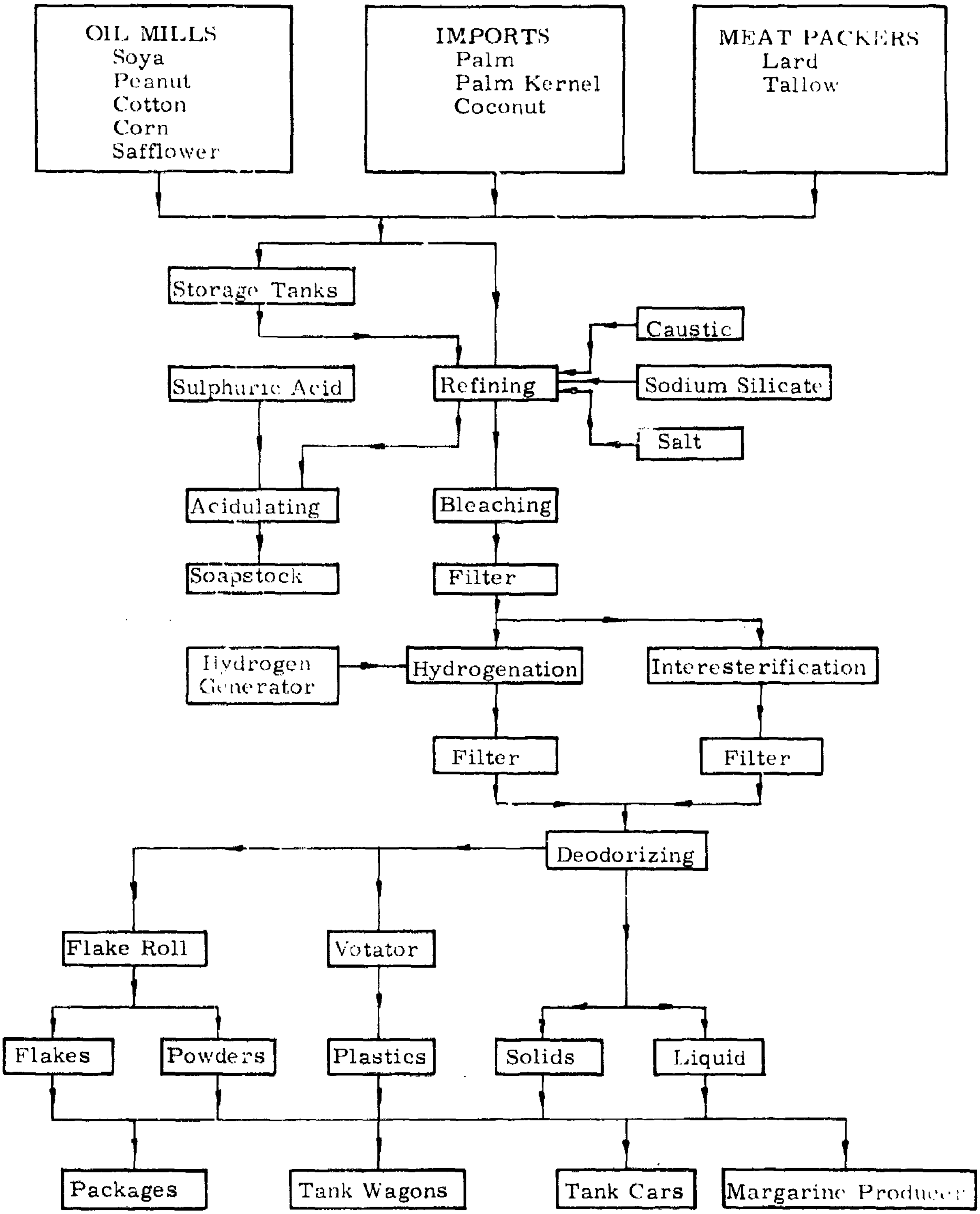


Figure 7-7 Flow Chart of Edible Oils Plant

7.2.3 Personnel

The edible oils plant maintains three 8-hour shifts, 7 days a week, and has four complete crews to keep this schedule in operation. The plant operates on a steady basis throughout the year with the following personnel requirements:

Office	30
Engineering and laboratory	10
Operating	110
Shipping and receiving	10
Maintenance	10
Machine shop	10
Steam plant	5
Hydrogen generation	5
Total	190

7.2.4 Shelter (within plant)

The edible oils plant has no shelter area provided and no provision for protection of personnel during a period of hazardous fallout. Fire would be extremely hazardous in this plant and therefore a shelter in a remote location away from the buildings would be indicated, especially with the possibility of oil tanks spilling or overflowing.

A number of areas could be marked as suitable for fallout protection. Lower floors in the process buildings have rooms remote from roof and ground contamination and would give considerable protection.

7.2.5 Shutdown and startup (normal)

Only a few employees are needed to carry out shutdown operations in the hydrogen and steam plants, which should be shut down carefully to prevent explosions; shelters should be provided for these personnel. The remainder can shut off their machines and leave immediately to seek community shelters wherever available.

All the equipment in the older buildings is manually operated and shutdown is initiated by the operator on duty. The feed to the unit is closed and the process continues until the equipment is empty. Usually a thorough cleanup follows to prepare for startup. The hydrogen plant is new and has automatic controls that must be adjusted to initiate shutdown. However, care must be taken to allow the unit to complete the shutdown cycle by clearing the hydrogen out of the system with some inert gas to prevent mixing oxygen with hydrogen to form an explosive mixture when the system is left idle. Therefore a routine shutdown is very important and may take several hours.

The fractionation plant has new equipment and automatic controls that require changing to a manual operation for final shutdown. Personnel must be on hand to complete the shutdown and clean out all equipment in preparation for startup.

Generally, the plant could be shut down for several weeks without too much deterioration in the product in process, if time did not permit the normal shutdown and cleanup procedure.

To start up again, however, requires a warmup period for tanks, pipelines, valves and equipment. This may take one day for some items, more for others, and actually may require 2 to 3 days work before it is possible to start the processing system, especially in the winter and this can only take place after the boilers have been fired long enough to provide steam heat. Otherwise process operation follows along routinely as soon as each unit can be supplied with material.

7.2.6 Utilities (normal)

Electric power

The plant uses 700,000 kilowatt hours per month and is supplied by an outside electrical company. Two lines come into the plant and are connected to transformers in several areas. Each area supplied with this transformed power is interconnected so that no area would be without power in an emergency unless, of course, both power lines are inoperative.

Water supply

Water is supplied through underground mains by the city in which the plant is located. Before water is introduced into the boilers, it is treated to remove chemicals which corrode boiler tubes.

Steam supply

Steam for processing heat is supplied by three boilers which could be fed either coal, oil or gas, depending on the price of the fuel. The boilers are run at 150 pounds pressure and supply 1,000,000 pounds of steam per day.

7.2.7 Repair and maintenance capability (normal)

This plant has an extensive, well-supplied repair and maintenance facility both in equipment and personnel. All machinery and process equipment are repaired in the plant's shops, and qualified personnel are available at all times. Major construction projects or installations require outside contractors to do extra work not of a routine maintenance nature. However, with the repair facilities available and with the personnel employed with experience in plant maintenance and repair, practically all repairs could be effected except those of a major type.

7.3 VULNERABILITY ANALYSIS

7.3.1 Low pressure blast range (0.0 psi to 2.0 psi)

Structural: In the low blast range, the damage incurred will be just sufficient to disrupt plant operations, excluding the effects of radioactive fallout. Repair will require up to 10 days.

Pump house

The composition roof of Building No. 17, the old pumphouse which is no longer in use, would shatter at 1.0 psi, and would therefore jeopardize plant operation by possibly damaging the electrical lines and junction boxes which are located within. Although a power failure could result from pieces of the roof acting as missiles, it is not likely because this equipment is protected by boxes and conduits and is supported by structures and hangers which are not tied into the roof.

Boiler stack

The 175-foot boiler stack on the west wall of the boilerhouse and the brick incinerator stack in the northeast corner of the boilerhouse have been analyzed from calculations based on similar stacks. The indications are that a condition of incipient masonry cracking would appear at 1.5 psi, in the low range of blast damage.

Fractionation plant

The fractionation plant has been designed with blowout panels as previously mentioned. These corrugated siding panels will blow in at 0.5 psi overpressure and will then leave the building in a reasonably good blast-resistant condition for much higher overpressures. The damage inside the fractionation plant from missiles created by the collapsing siding will not be severe, because of the heavy-duty construction of the tanks, pressure vessels, filters and presses. Damage would be mitigated by the fact that the corrugated asbestos siding is not sufficiently hard to do much damage as missiles. There is more instrumentation in the fractionation plant than elsewhere in the refinery, and this is naturally the most vulnerable aspect, from the point of view of missile damage in the low range.

Hydrogen gas plant

In the hydrogen plant, the brittle transite roof would fail rapidly at overpressures greater than 0.5 psi, thereby providing a clearing distance of 24 feet and allowing the walls to sustain an overpressure of 4.0 psi without failure. Without this failure of the roof, the clearing distance is increased to 55 feet and the wall failure would occur at 2.0 psi. Damage would be limited to gauges and instruments, which however, are essential to the hydrogen plant's operation because of the need for precise control of explosive gas. The danger of explosion, at any blast level, depends on the hydrogen being mixed with air to form an explosive mixture. This could happen if there was a leak in a storage tank or its piping. Hydrogen would leak out, and after a while air could start to leak into the tank, particularly if a drop in temperature created a partial vacuum within the tank. The danger of the escaped hydrogen exploding is not great because it would rise, rather than spread out into the area or into adjacent areas of the plant. Leaks in the hydrogen storage tanks could occur in the low range, but are more likely in the medium and high ranges.

Liquid storage tanks

The extent of damage to liquid storage tanks in the low blast damage range will depend on whether or not they are empty. Analysis and tests of liquid storage tanks indicate that the most frequent cause of failure is rupture of the seam between the bottom and wall of the tank, resulting from lifting of the tank from its foundation. The overpressures at which this would occur depend upon many factors other than well-made joints, such as the height-to-diameter ratio, the amount and weight of fluid in the tank, and the wall material and thickness. The tanks fail due to seam rupture at the bottom at overpressures as low as 1.0 psi when empty, but would stand much higher pressures even if half full.

Glass

Glass breakage in the low range will be quite extensive at 0.5 psi, and the missiles and litter created inside buildings will be quite widespread. Especially vulnerable to this type of damage are instruments and gauges. Contamination of product will, of course, result where it is exposed to dirt or flying glass.

7.3.2 Medium pressure blast range (2.0 psi to 7.0 psi)

Damage in the medium range is characterized by structural failures severe enough to shut down the plant for a period of approximately 60 days, and the man-day estimates of repair are based on this 60 day interval. The collapse of several walls, together with overturning of stacks and major damage to storage tanks contribute the bulk of the damage.

Boiler stack

Overturning of the 175-foot boiler stack will occur at approximately 3.0 psi, this being dependent on the direction of the blast and the amount of shielding that could be provided by the adjacent buildings. The incinerator stack will survive at overpressures slightly higher, up to 4.0 psi, because it has less height even though it has a shorter period of vibration than that of the boiler stack.

The damage caused by the collapse of the stacks could be considerable, depending on the direction in which they topple.

Main process group

A qualitative assessment of damage levels of roofs in the main process group, based on critical blast direction, yields the following: collapse of the closed penthouse roofs of No. 6 and No. 8 at 2.0 psi, and 5.0 psi to 6.0 psi for the roof of building No. 5. Other roofs will fail at higher blast levels.

The walls exhibit greater uniformity of resistance to blast than do the roofs. The absence of windows for several panels of the east wall, building 7, contribute to failure of this wall area at 6.0 psi. The walls of the closed penthouses will fail at 5.0 psi because of the slightly larger clear wall spans.

The process equipment in these buildings can be expected to suffer only minor damage at overpressures up to 3.0 psi. Severe equipment damage will not result until the blast pressure exceeds 6.0 psi.

Water tower

If it is empty, the water storage tower located above the roofs of buildings No. 6 and 7, will be blown off the roof at 3.0 psi because of collapse of its tripod support. The damage caused by this falling tank is slight compared to the damage it could cause, if full, by collapsing onto the roof of any of the adjacent buildings. This failure will occur at 4.0 psi due to column buckling of the tripod legs; this amounts to a weight of 250,000 pounds dropping onto buildings 5, 6 or 7. In building No. 5, this would probably knock out the Dowtherm boilers, and in the other buildings result in serious damage to process equipment.

Coal shaft

The coal shaft, being primarily a drag-sensitive structure, will probably fail at 5.0 psi. It is quite difficult to predict this failure with accuracy, because the inevitable corrosiveness of sulfuric acid and other acids, formed by coal impurities and moisture, affects the physical properties of the structural materials, and coal handling systems as old as this one are usually much weaker than when new.

Hydrogen gas plant

The hydrogen gas plant structure has an extensive window area. Thus, the glass will fail quickly, permitting a rapid equalization of overpressure inside. However, the critical blast direction for the structure is from the south because, although adjoined by another building, the non-glazed wall causes delay before interior pressure equalization. The transite roof fails at overpressures greater than 0.5 psi, followed by wall failure at 4.0 psi. The frame will remain standing unless subjected to an overpressure greater than 6.0 psi.

The outdoor storage tanks that are at least half full will experience severe damage from rupture of the seam between tank wall and base. This will occur at overpressures between 6.0 psi and 10.0 psi depending on the amount of liquid in the tank. Missile damage in this range is also an important consideration, because wind velocities will range from 70 mph. at 2.0 psi to 200 mph. at 6.5 psi overpressure, and puncturing or tearing of the tanks can be expected. The majority of outdoor storage tanks, then, will be unusable as a result of blast and missile damage in the medium range.

Storage tanks

There are a large number of storage tanks in various locations in the plant yard. Those located along the railroad track are for shipping and receiving and extend out from the process buildings. However, if tanks topple over, breakage would be extensive and spillage would be a problem. Tanks more than half full would remain standing at medium pressures, and if tanks are considerably more than half full they will remain intact in this range. This would save raw material for use when the plant is again ready for operation.

Other tanks clustered near the buildings are "in process" material tanks, and are assessed in much the same way as those above. Their contents would always vary and their chances of loss would be more difficult to predict. They are more involved with the process operation of the plant and will have to be repaired along with the plant facilities to return the plant to operating condition.

Pump house

In the medium range, walls without lateral support from the roof would collapse. Damage to the power lines would be more likely to occur in this range than in the low range, but no other consequences would result.

Acidulation building

Finally, the acidulation building, No. 29, will suffer severe damage. A complete lack of windows on the north wall make this wall sensitive to blast in the north-south direction. Although the roof will survive up to 7.0 or 8.0 psi, 6.0 psi will collapse the wall panels, and thereby save the frame from critical damage at this level. The truck entrance under the south end of the second floor, however, is subject to pressure turbulence, which could result in local failures in this area.

The acidulation building is used primarily for the processing of the heavier soapstock in wood tanks and is not, therefore, critical to production of edible oils.

Fractionation plant

The east wall which is solid will fail at 2.0 psi creating more damage to instrumentation than that caused by missiles in the low range.

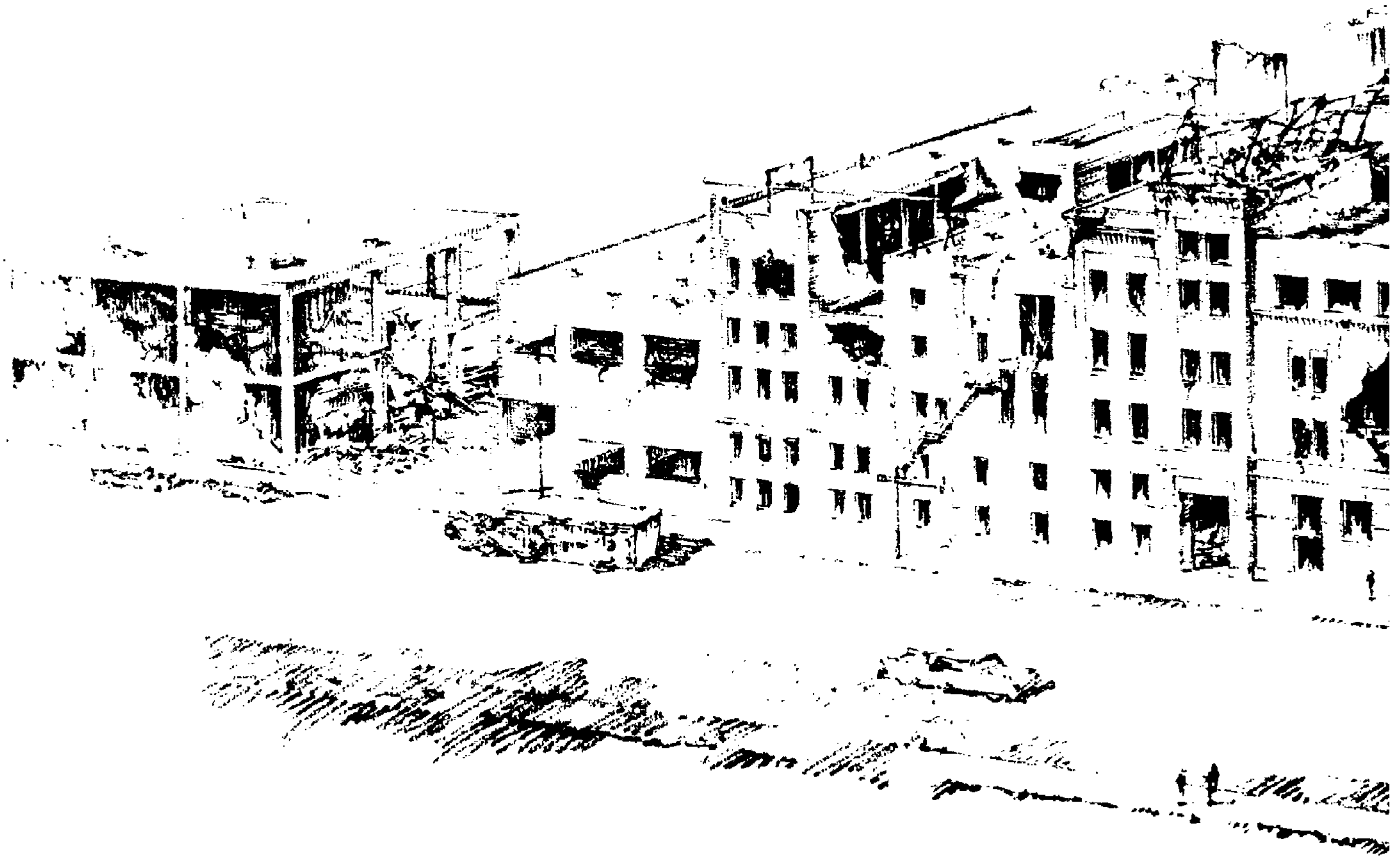
7.3.3 High pressure blast range (7.0 psi to 12.0 psi)

The blast damage in the high range is extensive particularly to roofs, walls and building frames, thereby creating major construction and repair problems.

The roof of buildings #2, 3, 4, 6, 7, 8, 9, 15 and the boilerhouse will all fail at 7.0 to 8.0 psi overpressure (see figure 7-8). In the case of building #2, the engine room and stills building, a blast from the east would damage the roof severly at 7.0 or 8.0 psi, in the course of equalizing internal and external pressures. Were the direction altered 180°, the blast front would strike the apertured wall first, shattering the glass and, progressing forward both inside and outside the building, provide a more nearly equal pressure on both sides of the roof, allowing it to survive blast pressures well over 8.0 psi.

The east face of building #2, with little window area would yield to an overpressure of 8 or 9 psi, but other walls of this building would remain intact at pressures up to 12 psi.

An analysis of the building frames in the process group would be redundant because of the massiveness of the party walls, concrete floors, and number and variety of room cells, all of which contribute to the support of the building.



Damage to Edible-O

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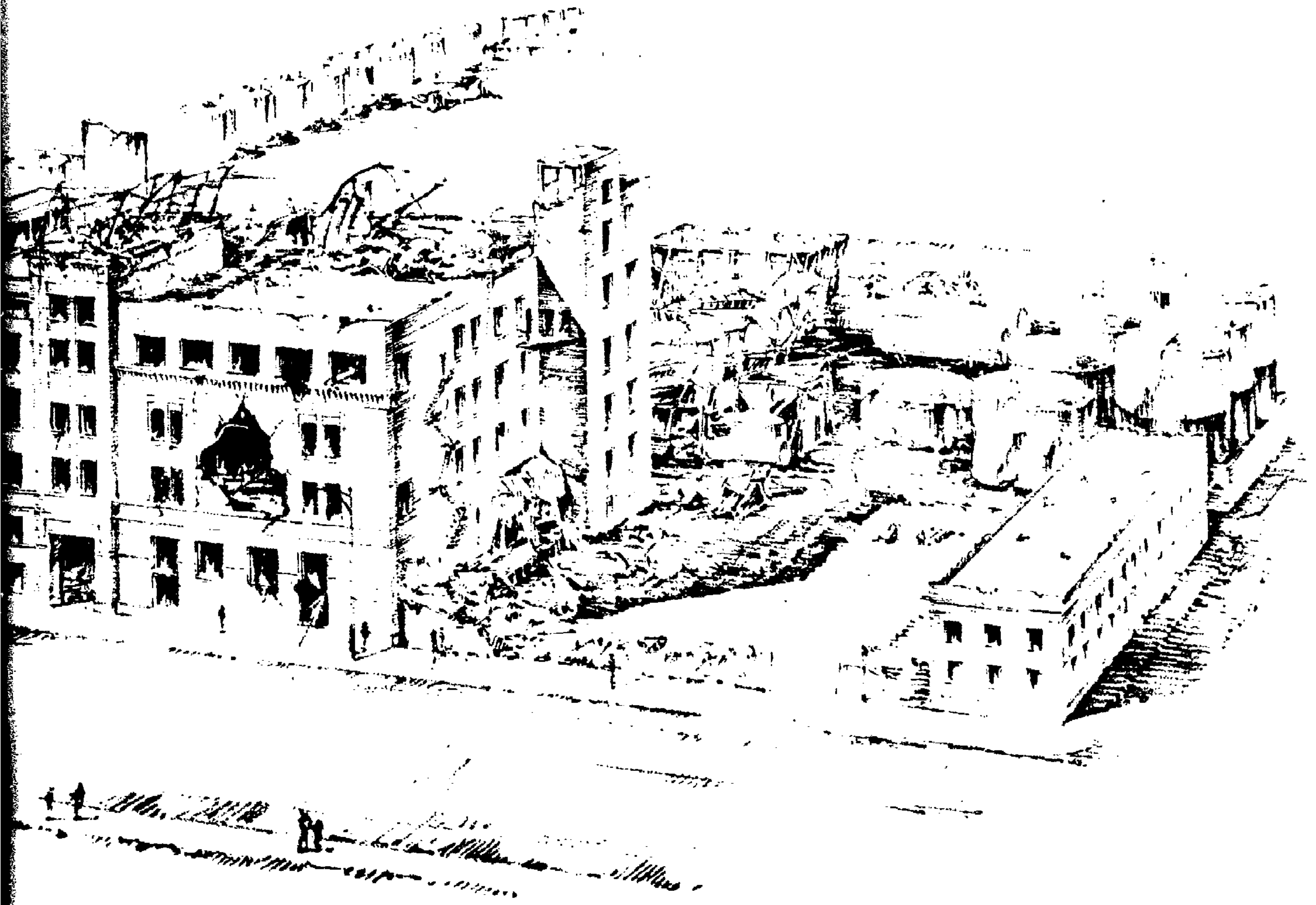

to Edible-Oils Plant at 7 psi Overpressure

Figure 7-8

The roof and frame of the fractionation building will remain standing up to 10.0 psi because the walls blow out at 2.0 psi, as already stated, equalizing internal pressures and exposing the frame to drag only.

7.3.4 Thermal radiation

Since the thermal pulse arrives at a location before blast damage is incurred, there is little danger of damage from thermal radiation. If there was any leakage of the hydrogen gas or if the hydrogen was vented to the air prior to the nuclear detonation, fire could occur from the thermal pulse.

7.3.5 Fallout

Danger of fallout contaminating the oil product is slight because all equipment is covered in order to keep dirt and dust out of the processing system under normal conditions. The only possibility of its entering the system would be in a vat or pipe which, at the time of attack, was in process of being overhauled or repaired.

7.3.6 Shutdown

A rapid shutdown is not a problem providing certain essential things are done, particularly in the winter months. For example, the hydrogen is stored over water in tanks and the water should be drained to prevent ice from tearing the tank. Venting the tank to release the hydrogen could create a fire by the thermal pulse igniting the gas if this were done too close to the time of the nuclear attack.

7.3.7 Bottlenecks and weak links

Typical of older structures is the ability of most of the plant's buildings to remain in satisfactory operating condition at a relatively high blast overpressure. The exception to this is the fractionation plant located in a separate building. This structure, newer than any of the others, has one wall which is completely solid. Any overpressure of 2.0 psi or greater will collapse the wall causing considerable damage. This does not hold up production of items which do not require this process, or that can bypass the fractionation process to produce a less refined product. But it would reduce the capacity for producing a complete line of standard products, and as a result, reduce considerably the normal production capacity of the plant.

The boiler stack overturns at 2.5 psi, which would again stop or reduce production to a small percentage of normal until damages can be repaired.

These items are the major weak links of the facilities which cause delay problems in the lower blast overpressures below 4.0 psi.

7.4 RECOVERY

7.4.1 Summary of damage

A summary of structural damage for the various levels of blast pressure will be found in table 7-1 and a similar summary for processing equipment is found in table 7-2.

7.4.2 Spare parts and cannibalization

The plant is well stocked in spare parts to be used for the repair or replacement of machinery components which are subject to normal wear.

There are so many different machines and types of processes involved that cannibalization would be difficult. Each machine has a separate function and would have to be repaired as a unit or left out of the process until it could be repaired or replaced. There are some tanks or mixers that could be used for work in the processing and cannibalization may be helpful; there are similar possibilities for filters and presses, but generally, prospects for cannibalization are not good.

The hydrogen plant is a complete unit in its own operation and would need complete repairing, testing and inspection before operation could be initiated after any damage.

The interesterification and deodorizing operations have multiple arrangements that could use some cannibalization for repair of one part or unit, and this might shorten the time for initiating some production.

The high range of blast damage would be so destructive to some specialized items of production that the product may have to be eliminated for a longer period of time than is indicated. If the factory or supplier of this needed equipment were able to replace parts and supply technicians to rebuild units, production could be returned to normal as specified.

7.4.3 Initiating emergency operation

For emergency operation of the plant following a nuclear blast, consideration will be given mainly to the condition and use of process equipment and materials. The structures are not considered as important for emergency operation other than for support or protection of process equipment.

Operation following low blast damage (0.0 psi to 2.0 psi)

With a blast of overpressure below 0.5 psi, process operations could resume as soon as personnel were safe from fallout radiation. When glass cracks and breaks, a clean up operation could take place while the plant continues to operate. Between 0.5 psi and 1.5 psi some damage may take place from missile effects of roofing and siding failures, but with minor repair the plant will be completely operable. Between 1.5 psi and 2.0 psi, the

Table 7-1 Summary of Damage to Structures

Pressure psi	Boiler House 1	Engine Room & Stills Bldg. 2	Refinery 3	Press Room Bldg. 4	Dowtherm Boiler House 5	Process Bldg. 6	Multi-Purpose Bldg. 7	Esterification Bdlg. 8	Deodorizing Bldg. 9	Hydrogen Gas Plant 14	Refining Bldg. 15	Deep Well Pump House 17	Acidulation Bldg. 29	Fractionation Bldg. 30	Boiler Stack	Incinerator Stack	Water Storage Tank	Coal Elevator	Exterior Storage Tanks
0.1	All glass shows cracking																		
0.5	All glazing shattered with occasional frame failure									Roofing Shattering				Siding Shattering					
1.0												Roof Shattering							(Empty) Cracking
1.5						Roof Penthouse Cracking		Roof Penthouse Cracking								Cracking	Cracking		
2.0														East Wall Collapse					
2.5															Overturn				
3.0																Overturn	(Empty) Overturn		
4.0										Walls Collapse							(Full) Collapse		
4.5																			
5.0					Roof Collapses	Walls Penthouse Collapse		Walls Penthouse Collapse				[illegible]lls Collapse						Frame Distortion	
6.0							Walls Collapse			Frame Distortion									(Half Full) Toppling
7.0	Roof starts To fail	Roof Collapse	Roof Collapse	Roof Collapse		Roof Collapse	Roof Collapse	Roof Collapse	Roof Collapse		Roof Collapse								
8.0									East Wall Collapse										
10.0														Frame Collapse					
	Walls of all remaining buildings cracking																		
12.0	Frames of all remaining buildings severely distorted																		

Table 7-2 Summary of Damages to Processing Equipment

Structural	Critical Overpressure	Processing Equipment
Glass cracking	.1	Dust in the equipment.
Glazing shattered #14 hydrogen gas plant roof shatters #40 fractionation plant siding shatters	.5	Debris and missile damage. Glass, gauges, and control damage. Missile damage to glass and instrumentation.
Bldg. #17 roof shatters Storage tanks (empty) cracking	1.0	Missile damage to power supply equipment. Loss of contents.
Boiler stack cracking Incinerator stack cracking #6 process bldg. penthouse roof collapse Bldg. #8 penthouse roof collapse	1.5	Boiler connection damage. Furnace connections damage. Filter presses in penthouse damaged. Filters and tanks in penthouse damaged.
Bldg. #40 east wall collapse	2.0	Debris and missile damage to fittings and controls.
Boiler stack overturns	2.5	Boiler connections destroyed, equipment damage.
Storage tanks (empty) collapse Incinerator stack overturns	3.0	Connections destroyed. Furnace connections destroyed, equipment damaged.
Bldg. #14 walls collapse Water storage tank (full) collapses	4.0	Pipes, valves, instruments and controls damaged. Connections destroyed, equipment damage.
#5 dowtherm boilerhouse roof collapse #6 process building, penthouse walls collapse #8 esterification building, penthouse walls collapse #17 pump house walls coll. Coal elevator frame distortion	5.0	Damage to boilers, auxiliary equipment and controls. Damage to press units and equipment. Damage to equipment in penthouse. Electric power equipment damaged. Elevator equipment damaged.

Table 7-2 Summary of Damages to Processing Equipment (Cont.)

Structural	Critical Overpressure	Processing Equipment
#7 multi-purpose bldg. walls collapse	7.0	Tanks processing and packaging equipment minor damage.
#14 gas plant frame distortion		Gas plant equipment and controls demolished.
#29 acidulation bldg. walls collapse		Tanks and equipment receive major damage.
Storage tanks - exterior (half full) - topple over		Tanks and piping major damage.
#1 boilerhouse roof failures	7.0	Boilers and auxiliary equipment badly damaged.
#2 engine room and stills building roof collapses		Stills near top floor badly damaged.
#3 refinery roof collapses		Refinery equipment top floor demolished.
#4 Press room roof collapses		Press equipment damaged.
#6 process bldg. roof coll.		Process machinery top floor demolished.
#7 multipurpose bldg. roof collapse		Top floor equipment demolished.
#8 esterification bldg. roof collapse		Tanks and equipment near the top floor demolished.
#9 deodorizing bldg. roof collapse		Tanks and equipment damaged.
#15 refinery bldg. roof collapse		Mixing tanks and filter equipment on top floor demolished.
#9 Deodorizing bldg. walls collapse	8.0	All process equipment damaged and demolished.
#40 fractionation bldg. frame collapse	10.0	Process equipment damaged and demolished.
All remaining walls cracking	11.0	Process equipment damaged throughout plant.
Frames of all bldgs. distort or collapse	12.0	Majority of process equipment demolished.

penthouses will have roof failures which effect some filters and tanks, but other units in the plant could easily pick up this operation with some minor delays or reductions in output. The low range has no emergency problems to initiate production and continued operation could be maintained at or near full capacity.

Operation following medium blast damage (2.0 psi to 7.0 psi)

At 2.0 psi, blast overpressure failures will start to take place that will cause considerable delay in repair and recovery of the damaged process equipment. Near 2.5 psi, the boiler stack will overturn and create the first difficult problem. Heat is necessary to handle and process the crude oils, which makes it mandatory to reestablish the stack and place the boilers in operation before any production can be initiated.

At higher pressures, walls will collapse, the incinerator stack overturns, building roofs will collapse, and these incidents will each require repair and rebuilding for recovery. However, after removal of debris, replacing the stack, and cleaning of equipment, some production could be established without repairing the buildings. The failure of the coal elevator at 5.0 psi would prevent continued boiler operation until some means of supplying coal to the furnaces could be established. Some temporary conveyor units could be used to maintain emergency operation.

Near 6.0 psi, the gas plant is badly demolished and would have to be rebuilt. Basic production could bypass the hydrogenation process to supply consumer demand. The production of high quality special types of oils would not be possible, but the basic products are the important items to maintain in an emergency situation.

Over the medium range, many items will fail or be damaged, necessitating repairs, but there are so many tanks and arrangements of piping that circulation of material could be rerouted to different tanks and production could be maintained. This is an important feature of this type of plant. The basic oils are satisfactory to use for survival in many of the stages of processing from the raw material to the various special items that are made.

Apart from the difficulty encountered when the boiler stack overturns, production could be maintained by rearranging the flow through the plant to provide a clean product for emergency requirements.

Operation following high blast damage (7.0 psi to 12.0 psi)

Over the high range, ability to provide some production will decline with the loss of each production unit. Rerouting can be done, but the loss of equipment continues to reduce the capacity for production right down to the collapse of the last buildings and the demolishing of the last usable process units.

Cleaning away debris around any unit is of prime importance to make it accessible. Almost any tank or vat is good for supplying chemicals to improve the product, and for mixing and working if some means of heating is provided to maintain flow temperatures. Manual labor may have to help with some of these operations, but under emergency operations some product could be supplied to assist in survival as long as vats and equipment can be made useful and the material is accessible.

7.4.4 Shortcuts

A great deal of time and effort go into providing special types of products to suit different customers in their specialty items, and much of this could be eliminated by the processing of standard, non-fancy, less refined oil which would serve the purpose in the postattack period.

7.4.5 Utilities

Electric power

Electric power is essential to run the many electric motors which drive the pumps, agitators and filter presses. Without power the oils could not be pumped through the piping in the process system. Electrical facilities should therefore be restored as soon as possible to start even an emergency operation.

Water supply

With the city water mains underground, the mains are invulnerable, but any damage to above-ground connections within the building or on the roof at the water tank could result in a serious loss of water for firefighting purposes and the water supply for the hydrogen tanks. Water mains should be shut off prior to an attack, if possible.

Steam supply

A considerable amount of steam is used per day for processing. Fortunately, the boilerhouse will remain intact except for glass missile damage until 7.0 psi. The boilers should be repaired as soon as possible for an emergency operation.

7.4.6 Repair required to resume normal operation

Low blast pressure range

The damage incurred in the low range is insufficient to disrupt plant operations for very long.

All glass windows will require repairing and the roofs of the gas plant and pumphouse will need repairing as does the siding of the fractionation building. The storage tanks, if empty at the time of the attack, the boiler and incinerator stacks all will show signs of cracking and will require inspection and repair, particularly the tanks.

At the high end of this range, 1.5 psi, the collapsed penthouse roofs will need rebuilding.

Medium blast pressure range

At 2.0 psi, the rubble from the collapsed east wall will have to be removed and a new wall built. The instrumentation will require checking and repairing.

Between 2.5 and 4.0 psi, the boiler stacks will require considerable cleanup of debris and rebuilding. Depending on the direction of collapse and the missile damage that results, equipment in the area may or may not need considerable repair. If the stacks should collapse in the direction of other structures, considerable additional damage would take place, which has not been accounted for in the repair requirements, and some additional labor and repair work would be necessary. Empty storage tanks which show cracking will have to be welded, and those which have collapsed will require rebuilding to take care of future continuous operation. Tanks, however, can be repaired after the necessary equipment has been repaired.

At 4.0 psi, the collapsed walls will need rebuilding and the equipment which operates under pressure will need cleaning, with careful checking to make sure all damage was repaired for safe operation under pressures. This will require testing of equipment before operation can be resumed. The failure of the water tower at 4.0 psi will necessitate a great deal of repair to the roof of the building on which it falls, depending on the direction of the blast. The water tower should be rebuilt eventually for future fire protection, but it has no role in the processing system.

At 5.0 psi, the collapsed Dowtherm building roof will require the cleanup of debris and the equipment below would require cleaning, checking and general repair in order to bring it up to operating condition. Because of steam pressure in the equipment, careful checking will be required on all repair work. The penthouse walls at the process building and the interesterification building will require rebuilding as will those walls at the deep well pumphouse. The equipment in the penthouses is generally of rugged construction and would only require cleaning up. The deep well pumphouse, now used only as a housing for the incoming power lines, will require the equipment to be thoroughly checked to make certain the electric power connections are reliable and safe to use. Most of this work in the pumphouse will require the efforts of electricians to check and repair insulation, connections and controls.

The coal elevator will have considerable frame distortion at 5.0 psi and will have to be repaired as soon as possible to get the boilers back in operation. At this point of general damage, it should be easily possible to repair, ready for use as soon as any other equipment is ready for operation.

Near 6.0 psi, the collapsed walls of the #7 multipurpose building will mean rebuilding the walls after a complete cleanup and removal of dust and debris. The equipment will need cleaning to make sure it is sanitary and safe to operate. Missile damage will be considerable and a great deal of repair work would be necessary. The distorted frame will probably require extensive repair and rebuilding in some locations. Considerable repair work on tanks and equipment will be required, as will careful testing for safety.

There are a large number of storage tanks in various locations in exterior areas. Those located along the railroad track are for shipping and receiving, and extend out and away from the process buildings. At 6.0 psi, they would tend to topple over even if half full. The lifting effect of the sides from the bottom even at lower pressures may tend to crack the joint and allow leakages to start. If tanks topple over, breakage would be extensive and spillage would be a problem. Tanks more than half full would remain standing, however, at this pressure, and it appears that if tanks are considerably more than half full they should remain intact along with the structures to be available even into the high blast damage range. This would save raw material for use when the plant is again ready for operation.

The "in process" material tanks are directly involved with the process operation of the plant and will have to be repaired along with the plant facilities to keep the process operation in progress. The spillage and cleanup would require considerable work before repair work could even be started.

The missile damage from flying debris at the higher pressures in this range are likely to create extensive damage in all parts of the plant, and accounts for the rather high repair figures indicated. Some of the newer processes now in use have more complicated and vulnerable equipment that requires specially trained technical personnel to supervise, and repairs and startup operations would have to be carried out under their guidance with the proper care taken in testing and inspection. Older equipment in some parts of the plant can be cleaned and serviced more easily and with less-trained personnel under the attention of a supervisor.

High blast pressure range

At 7.0 psi, the boilerhouse roof will need repair but the roofs of buildings #2 through #9 and #15 will have to be rebuilt after a considerable cleanup effort. A great deal of repair will be required on all equipment on the top floors under these roofs.

At 10.0 psi, the debris of the collapsed frame of the fractionation building should be removed and a new frame built. The equipment inside will require a great amount of repair -- on the order of 4000 man-days because of the great amount of instrumentation and piping in the building.

At 11.0 psi, all remaining undamaged walls would be damaged. This would result in major construction on all buildings and major repair throughout the whole facility on process equipment and machinery. It would require a large number of men of all types from labor to engineers, cleaning up, checking and evaluating damage to determine what is economical to repair and what needs to be replaced to obtain complete recovery. This is the last blast pressure area that is considered for recovery because at 12.0 psi the blast distorts or collapses all building frames and the damage would be so extensive the plant could not be considered economically repairable, but rather would require complete rebuilding as a new plant.

7.4.7 Substitutes

If all edible oil production were eliminated, substitution would largely depend on the ingenuity of the average householder. Fats and oils that are normally thrown out, such as bacon grease and beef or pork fat, could be saved and used to replace cooking oils. Some foods, such as canned sardines, come packed in oil which could be saved and used in cooking, provided stocks of these foods were on hand in postattack homes or grocery stores. A trend of long standing could be reversed, with the substitution of butter for margarine.

7.4.8 Increased production capability

The plant now works three shifts per day maintaining four crews operating on a continuous operating basis, seven days a week. The plant is normally operating at full capacity giving very little opportunity for any significant increase in production.

7.4.9 Estimated man-days required for each level of blast pressure

The repair effort will be found in the following charts. The recovery chart which graphically illustrates the contents of the repair estimates will be found in figure 7-9.

EDIBLE OILS PROCESSING PLANT

Low Blast Damage Range 0.0 to 2.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
0.1	glass cracking	clean up	labor	10	10	100
0.5	all glazing shattered	pick up glass dirt and debris repair windows and replace new glass	labor	50	10	500
	#14 H_2 gas plant roof shatters	rebuild roof	tradesmen	30	10	300
	#40 fractionation siding shatters	replace siding	tradesmen	30	10	300
1.0	#17 pump house roof shatters	rebuild roof	tradesmen	3	10	30
	storage tanks (empty) cracking	repair tanks	tradesmen	30	10	300
1.5	boiler stack cracking	check over and repair	labor tradesmen	10	10	100
	incinerator stack cracking	check over and repair	labor tradesmen	10	10	100
	#6 process bldg. - Penthouse roof collapse	clean up and rebuild	labor tradesmen	30	10	300
	#8 Ester. bldg. - Penthouse roof collapse	clean up and rebuild	labor tradesmen	30	10	300
			Structural			2,330

EDIBLE OILS PROCESSING PLANT

Low Blast Damage Range 0.0 to 2.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS					
0.1	glass cracking	clean up equipment	labor	10	10	100
0.5	glass in equipment missile damage	equipment dismantled and cleaned as required -- repairs from missile dam.	labor technicians	40	10	400
	bldg. #14 roof shatters	clean up equipment - repair broken glass, gauges and controls	labor technicians	20	10	200
	bldg. #40 siding shatters	clean up and repair missile damage	labor technicians	150	10	1500
1.0	#17 pump house roof shatters	clean up and check power lines	labor technicians	3	10	30
1.5	storage tanks (empty) cracking	clean tanks and repair	labor tradesmen	20	10	200
	boiler stack cracking	check connections to boiler	tradesmen	2	10	20
	incinerator stack cracking	check connections to boiler	tradesmen	2	10	20
	#6 process bldg. p'hse. roof failure	clean, check & repair	labor	30	10	300
	#8 ester. bldg. p'hse. roof failure	clean, check & repair	labor	30	10	300
			Process			3,070
			Structural			2,330
		Total Man-Days for Low Range				5,400

EDIBLE OILS PROCESSING PLANT

Low Blast Damage Range 0.0 to 2.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
	clean up debris			50	10	500
	Process					
	clean, repair and replace equipment			50	10	500
		Total Man-Days for Low Range				1,000

EDIBLE OILS PROCESSING PLANT

Medium Blast Damage Range 2.0 to 7.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
2.0	#40 east wall collapse	clean up check & repair	labor tradesmen	25	60	1500
2.5	boiler stack overturning	clean up rebuild	labor tradesmen	8	60	480
3.0	water storage tank (empty) collapses	clean up rebuild	labor tradesmen	10	60	600
	incinerator stack overturning	clean up rebuild	labor tradesmen	5	60	300
4.0	#14 H_2 gas plant walls collapse	clean up rebuild	labor tradesmen	25	60	1500
	Water storage tank (full) collapses	clean up rebuild	labor tradesmen	15	60	900
5.0	#5-dowtherm boiler hse. roof collapses	clean up rebuild	labor tradesmen	20	60	1200
	#6-process bldg. walls of penthouse collapse	rebuild	labor tradesmen	10	60	600
	#8-ester. bldg. walls of penthouse collapse	rebuild	labor tradesmen	10	60	600
	#17-deep well pump hse. walls collapse	clean up rebuild	labor tradesmen	2	60	120
	Coal elevator frame distortion	repair frame	tradesmen	2	60	120
6.0	#7 multi-purpose bldg. walls collapse	clean up rebuild	labor tradesmen	30	60	1800
	#14 H_2 gas plant frame distortion	clean up rebuild	labor tradesmen	30	60	1800
	#29 acidulation bldg. walls collapse	clean up rebuild	labor tradesmen	30	60	1800
	Storage tanks exterior half-full topple over	clean up repair-rebuild	labor tradesmen	25	60	1500
			Structural			14,820

EDIBLE OILS PROCESSING PLANT

Medium Blast Damage Range 2.0 to 7.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS					
2.0	#40 east wall collapse	clean, check & repair	labor tradesmen	5	10	50
2.5	boiler stack overturning	clean & check & repair equip.	labor tradesmen	5	60	300
3.0	storage tank (empty) collapses	check piping valves & connec.	tradesmen	3	60	180
	incinerator stack overturning	clean, check & repair equip.	labor tradesmen	5	60	300
4.0	#14 H_2 gas plant walls collapse	clean, check & repair equip.	labor technicians	20	60	1200
	water storage tank full - collapse	repair & replace all connections	labor tradesmen	5	60	300
5.0	#5 dowtherm boiler house roof collapse	clean equip. check, repair & replace parts	labor technicians	20	60	1200
	#6 process bldg. walls of p'hse. coll.	clean & repair equipment	labor technicians	5	60	300
	#8 ester. bldg. walls penthouse collapse	clean & repair equipment	labor technicians	5	60	300
	#17 deep well pump house walls collapse	repair power lines & supports	tradesmen	2	60	120
	coal elevator frame distortion	check & repair equipment	tradesmen	2	60	120
6.0	multi-purpose bldg. wall collapse	clean, check & repair equip.	labor technicians	20	60	1200
	#14 H_2 gas plant frame distortion	clean, check & repair & replace equip.	labor tradesmen technicians	20	60	1200

EDIBLE OILS PROCESSING PLANT

Medium Blast Damage Range 2.0 to 7.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS (Cont.)					
6.0 (Cont.)	#29 acidulation bldg. walls collapse	clean, check & repair & replace equip.	labor tradesmen technicians	25	60	1500
	exterior storage tanks (half full) topple over	clean, check & repair equip.	labor tradesmen	10	60	600
			Process			8,870
			Structural			14,820
		Total for 2.0 psi to 7.0 psi				23,690
		Total for Low Range				5,400
		Total Man-Days for Med. Range				29,090

EDIBLE OILS PROCESSING PLANT

Medium Blast Damage Range 2.0 to 7.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
2.0	clean up collapsed wall at building #40			12	25	300
2.5	rebuild boilerhouse stack			40	25	1000
4.0	clean up collapsed wall at building #14			4	25	100
5.0	clean up debris of roof collapse at building #5			4	25	100
	clean up collapsed walls at buildings #6, 8, and 17			4	25	100
	repair coal elevator frame			12	25	300
6.0	clean up collapsed walls at buildings #7 and 29			8	25	200
	Process					
2.0	make minimum repairs to equipment in building #40			12	25	300
2.5	clean, check and repair boiler-house connections to stack			8	25	200
4.0	clean, check and repair equipment in building #14			8	25	200
5.0	clean, check and repair equipment in buildings #5, 6, 8, and 17			32	25	800
	make minimum repair to distorted coal elevator frame			4	25	100
6.0	clean, check, and repair equipment in buildings #7, 14, and 29			36	25	900
	repair storage tanks			24	25	600
	Total for 7.0 psi to 12.0 psi					5,200
	Total for Low Range					1,000
	Total Man-Days for Medium Range					6,200

EDIBLE OILS PROCESSING PLANT

High Blast Damage Range 7.0 to 12.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
7.0	#1 boilerhouse roof starts to fail	clean up repair	labor tradesmen	20	100	2000
	#2 engine rm. and stills bldg. roof collapses	clean up and rebuild	labor tradesmen	10	100	1000
	#3 refinery roof collapses	clean up and rebuild	labor tradesmen	10	100	1000
	#4 press room roof collapses	clean up and rebuild	labor tradesmen	3	100	300
	#6 process bldg. roof collapses	clean up and rebuild	labor tradesmen	3	100	300
	#7 multipurpose bldg. roof collapses	clean up and rebuild	labor tradesmen	5	100	500
	#8 esterification bldg. roof collapses	clean up and rebuild	labor tradesmen	5	100	500
	#9 deodorizing bldg. roof collapses	clean up and rebuild	labor tradesmen	4	100	400
	#15 refining bldg. roof collapses	clean up and rebuild	labor tradesmen	5	100	500
8.0	#9 deodorizing bldg. east wall collapses	clean up rebuild	labor tradesmen	10	100	1000
10.0	#40 fractionation bldg. frame collapses	clean up rebuild	labor tradesmen engineer	40	100	4000
	Note: At 12.0 psi or above it is uneconomical to repair the plant					
			Structural			11,500
12.0	frames all distorted or collapsed	rebuild				

EDIBLE OILS PROCESSING PLANT

High Blast Damage Range 7.0 to 12.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS					
7.0	#1 boilerhouse roof starts to fail	clean, repair & replace equipment	labor technicians engineer	20	100	2000
	#2 engine rm. and stills bldg. roof coll.	clean, repair & replace equipment	labor tradesmen technicians engineer	15	100	1500
	#3 refinery roof collapses	clean, reapir & replace equip.	labor tradesmen technicians engineer	10	100	1000
	#4 press room roof collapses	clean, repair & replace equip.	labor tradesmen technicians	2	100	200
	#6 process bldg. roof collapses	clean, repair & replace equip.	labor tradesmen technicians	3	100	300
	#7 multipurpose roof collapses	clean, repair & replace equip.	labor tradesmen technicians engineer	5	100	500
	#8 esterification bldg. roof collapses	clean, repair & replace equip.	labor tradesmen technicians engineer	5	100	500
	#9 deodorizing bldg. roof collapses	clean, repair & replace equip.	labor tradesmen technicians engineer	4	100	400
	#15 refining bldg. roof collapses	clean, repair & replace equip.	labor tradesmen technicians engineer	5	100	500
8.0	#9 deodorizing bldg. east wall collapses	clean, repair & replace equip.	labor tradesmen technicians engineer	5	100	500
10.0	#40 fractionation bldg. plant frame collapses	clean, repair & replace equip.	labor tradesmen technicians engineers	40	100	4000

EDIBLE OILS PROCESSING PLANT

High Blast Damage Range 7.0 to 12.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	PROCESS (Cont.)					
11.0	walls all cracking collapsed	clean, repair & replace equip.	labor tradesmen technicians	100	100	10,000
			Process			21,400
			Structural			11,500
		Total for 7.0 psi to 12.0 psi				32,900
		Total for Medium Range				29,090
		Total Man-Days for High Range				61,990
12.0	frames all distorted or collapsed					

EDIBLE OILS PROCESSING PLANT
High Blast Damage Range 7.0 to 12.0 psi

Pressure Range (psi)	Damage	Repair		
		Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION			
	Structural			
7.0	clean up debris at buildings #1 and 15	40	50	2000
8.0	clean up additional debris at building #8	4	50	200
10.0	clean up debris at building #40	16	50	800
11.0	clean up debris at all buildings with collapsed walls	20	50	1000
	Process			
7.0	clean up, repair, and cannibalize all equipment at buildings #1, 9, and 15	60	50	3000
8.0	same at building #9 for additional damage to equipment	6	50	300
10.0	same at building #40	40	50	2000
11.0	clean up, repair, and cannibalize equipment in all buildings with collapsed walls	100	50	5000
	Total for 7.0 psi to 12.0 psi			14,300
	Total for Medium Range			6,200
	Total Man-Days for High Range			20,500

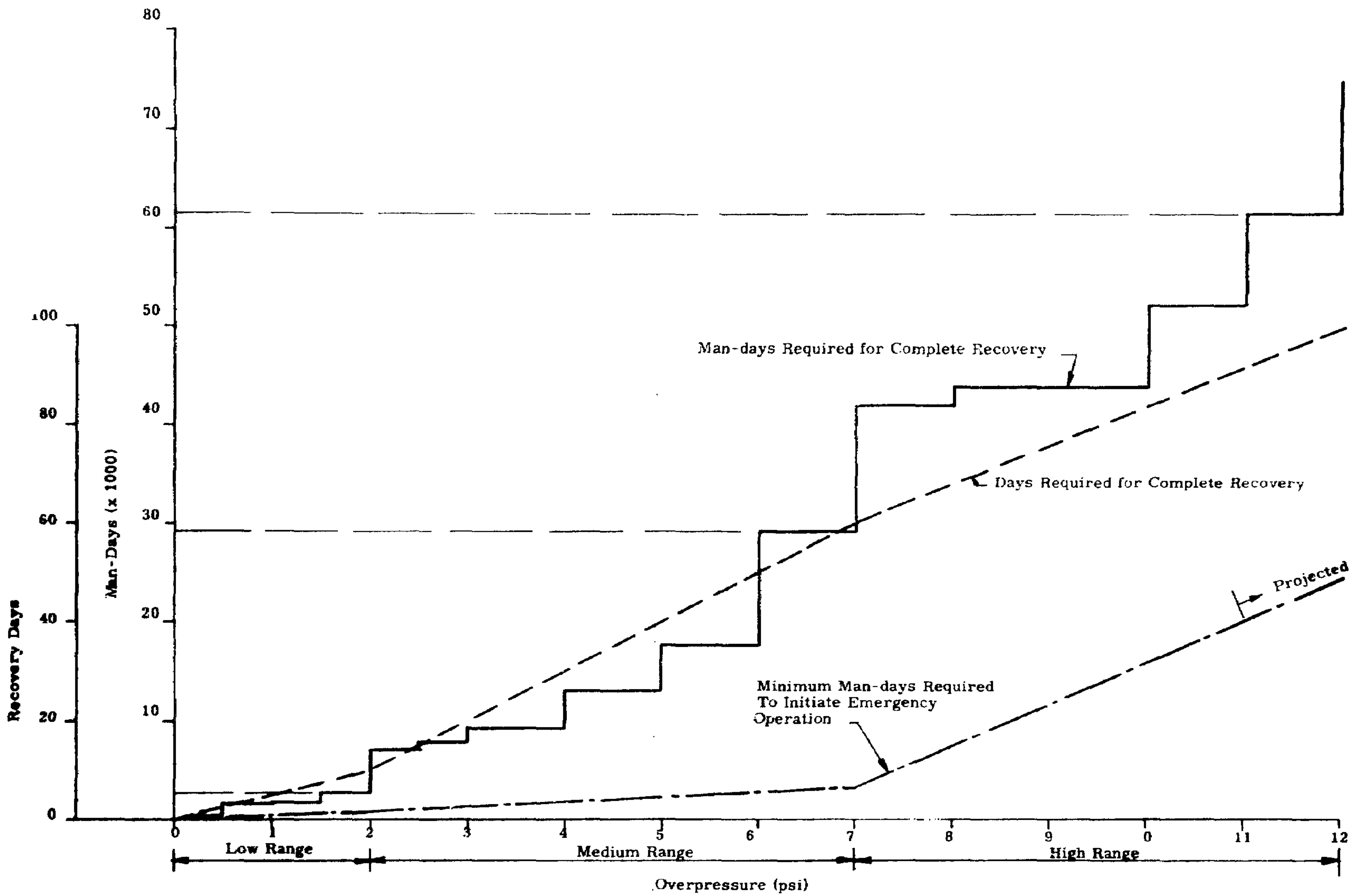

Figure 7-9 Recovery Chart - Edible Oils Plant

7.5 CONCLUSIONS

Edible fats and oils were studied at a plant of Durkee Famous Foods Division of Glidden Industries located in Chicago, Illinois. The plant selected, although old, is versatile and capable of making virtually any variety or type of product required by modern industry.

Due to its massive construction, and to the fact that the plant is actually a grouping of buildings, some sharing common walls, this was, overall, the most blast-resistant structure studied. Fire is not a particular hazard, due to the high flash points of the oils. Damage ranges: low 0.0 - 2.0; medium 2.0 - 7.0; high 7.0 - 12.0. A possible weak link is the collapse of the water tower. Shutdown is not a problem. Shortcuts include the processing of standard, non-fancy, less refined oils which would serve the purpose almost as well, and substitutes include the saving and use of animal fats and oils (e.g. bacon grease) normally thrown away by housewives.

The trend to packaged mixes seems quite significant over the longer run, which could greatly simplify the postattack supply problem.

8. THE FISHING INDUSTRY

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8. FISHING INDUSTRY

8.1 REVIEW OF THE INDUSTRY

8.1.1 General

As compared with most of the rest of the world, Americans consume relatively little fish due, perhaps, to affluence and a preference for the more expensive meat products. The average American consumed only ten pounds of fish in 1963, about 40 percent of it canned, as compared with approximately 40 pounds per capita for Japanese and Scandanavians, and 22 pounds for the English.[30] There has been no appreciable change in the rate of consumption in the United States during recent years, and none appears imminent. In terms of its place in the diet, fish is presently of minor importance but could have postattack significance as a supplement to meat.

Tuna has superseded salmon as the number one fish in volume of domestic consumption. In order of volume, the ranking of the various species is shown in the table 8-1. Shrimp and salmon are virtually tied for first place in total value of all fish landed, yet represents only a small percent of total volume. Menhaden, on the other hand, rank twenty-sixth in value, yet account for almost half of all fish landed, in weight. The discrepancy is explained by the fact that menhaden are not used in human consumption, but rather are turned into industrial fats and oils, animal feed, bait, and fish flour. The latter is rather tasteless product, but a nutritious one. Food and Drug Administration rulings prevent its use in the United States at present, but because of its low cost and abundance, menhaden fish flour could represent an important food reserve, requiring no refrigeration.

Maine "sardines" are young sea herring, rather than the true sardines, or pilchards, found off Norway and the American Pacific Coast. They are netted in the coastal waters of Maine and packed in 31 canneries in the state. In common with the rest of the fishing industry, the approach in sardine fishing is essentially one of hunting, rather than husbandry, and consequently the catch is erratic. For example, the 1961 catch of 54.5 million pounds (754,000 cases) was one-third that of the preceding year. Maine sardines, and canned fish in general, enjoy certain postattack advantages over fresh meat. Not only does the canned fish keep without refrigeration, but fish, because they are found in the sea, are less vulnerable to fallout than land animals.

8.1.2 Geographical locations of fish canneries

There are 366 plants producing canned fishery products in the United States, (see figure 8-1) including American Samoa and Puerto Rico, and 205 of them are on the Pacific coast, including Alaska. Other major areas are the south Atlantic and Gulf states, with 59 plants, and New England with 50.

They pack about 1,000,000,000 lbs., (33,000,000 cases) of fish per year. Of this total, animal food accounts for approximately 9,400,000 cases.

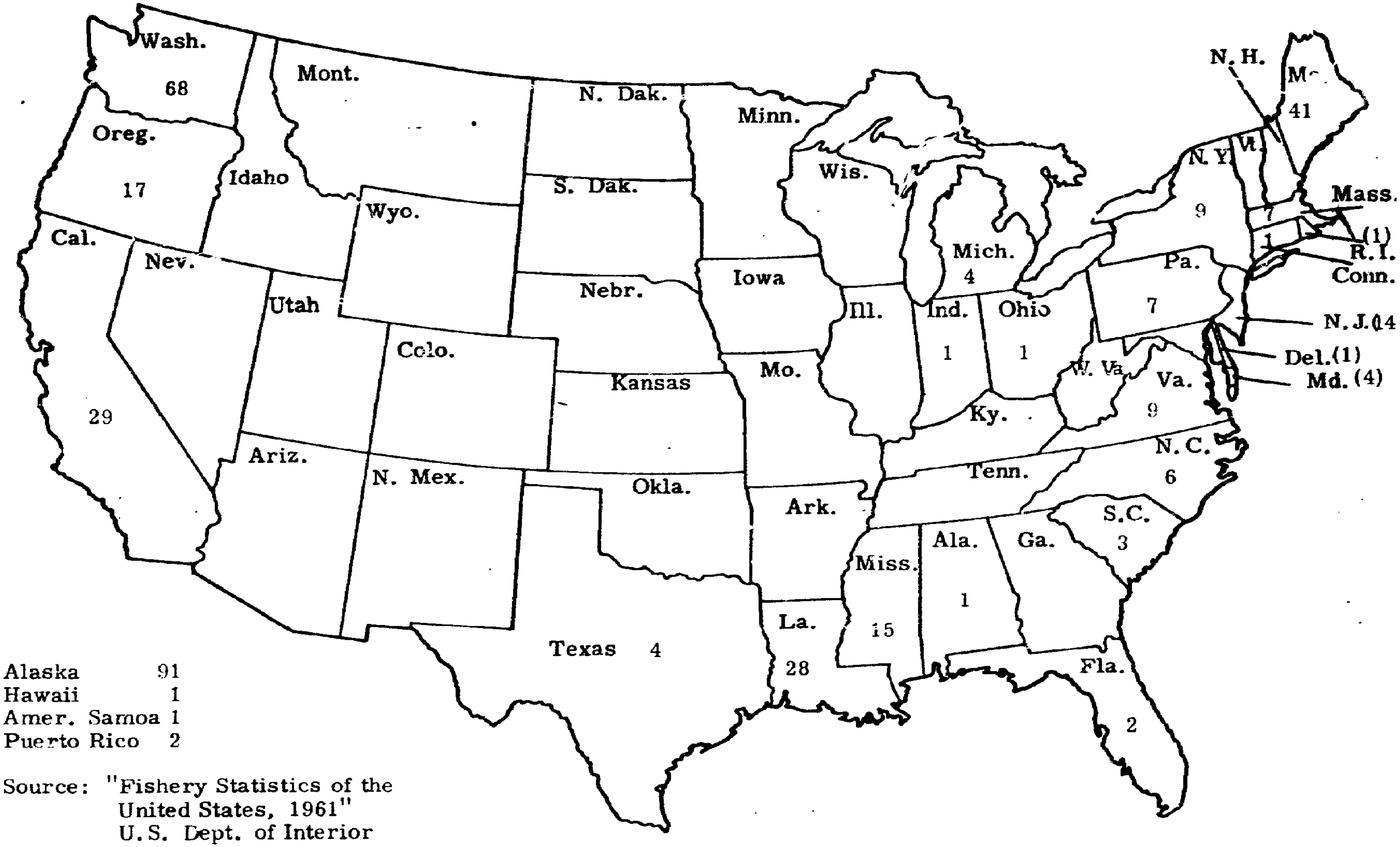
Table 8-1 United States Catch, 1961*

Species	Quantity (x 1000)	Percent of Total Catch	Value (x 1000)	Percent of Total Value
Menhaden	2,314,677 lbs.	44.6	$ 25,579	7.0
Tuna	325,804	6.3	42,346	11.7
Salmon	310,398	6.0	52,027	14.4
Crabs	231,606	4.5	17,337	4.8
Shrimp	174,530	3.4	51,688	14.3
Industrial Fish	146,786	2.8	1,814	0.5
Haddock	133,597	2.6	9,907	2.7
Flounders	133,111	2.6	12,663	3.5
Ocean Perch, Atl.	132,062	2.6	5,114	1.4
Herring, Sea:				
Atlantic	58,243	1.1	1,102	0.3
Maine Sardines	(54,000)			
Pacific	54,491	1.1	7.0	0.2
Whiting	100,729	1.9	2,245	0.6
Jack Mackerel	97,810	1.9	2,109	0.6
Oysters	63,305	1.2	33,204	9.2
Alewives	56,077	1.1	716	.2
Halibut, Pacific	53,238	1.0	8,408	2.3
Clams	50,330	1.0	11,661	3.2
Cod:				
Atlantic	46,591	0.9	2,995	0.8
Pacific	3,067	0.1	150	0.1
Scup or Porgy	46,584	0.9	2,931	0.8
Mackerel, Pacific	44,110	0.9	956	0.3
Sardine Pacific	43,170	0.8	1,146	0.3
Mullet	42,813	0.8	2,543	0.7
Catfish & Bullheads	38,468	0.7	6,352	1.8
Carp	30,901	0.6	1,098	0.3
Lobsters, Northern	27,998	0.5	14,572	4.0
Scallops, Sea	27,461	0.5	10,404	2.9
Rockfishes	24,882	0.5	1,137	0.3
Pollock	21,406	0.4	795	0.2
Mussel Shells	16,519	0.3	904	0.2
Chubs	16,516	0.3	2,128	0.6
Buffalofish	15,823	0.3	1,837	0.5
Squid	13,692	0.3	490	0.1
Snapper, Red	12,688	0.2	3,266	0.9
Sheepshead, Fresh-Water	12,491	0.2	523	0.1
Ocean Perch, Pacific	12,443	0.2	594	0.2
Whale Products	11,824	0.2	847	0.2
Herring, Lake	11,702	0.2	653	0.2
Butterfish	10,225	0.2	948	0.3

Table 8-1 United States Catch, 1961 (Continued)

Yellow Perch	9,694	0.2	1,277	0.4
Striped Bass	9,495	0.2	1,270	0.4
Hake, Red	8,773	0.2	-----	
Bonito	8,653	0.2	-----	
Lingcod	7,999	0.2	-----	
Spot	7,912	0.2	560	0.2
Anchovies	7,783	0.2	-----	
Spanish Mackerel	7,433	0.1	752	0.2
Groupers	7,264	0.1	765	0.2
Shad	7,256	0.1	1,243	0.3
Irish Moss	6,995	0.1	-----	
Sablefish	6,704	0.1	693	0.2
Sea Bass, Black (Atlantic)	6,405	0.1	1,090	0.3
Smelt	5,484	0.1	-----	
Sea Trout or Weakfish, Spotted	5,380	0.1	1,283	0.4
Hake, White	5,214	0.1	-----	
Croaker	5,175	0.1	762	0.2
King Whiting or "Kingfish"	4,545	0.1	-----	
Sea Trout or Weakfish, Gray	4,471	0.1	1,283	0.4
Unclassified	86,906	1.7	10,060	2.8
Total	5,186,709 lbs.	100.0%	$362,210	100.0%

*Source: "Fishery Statistics of the U.S., 1961, U.S. Dept. of Interior



Alaska 91
Hawaii 1
Amer. Samoa 1
Puerto Rico 2

Source: "Fishery Statistics of the United States, 1961" U.S. Dept. of Interior

Figure 8-1 Distribution of Plants Producing Canned Fishery Products, by States, 1961

8.1.3 Sources of supply

Table 8-2 breaks down the total catch, both salt and fresh water, for the individual states. Louisiana is the leading fishing state, followed by California, Massachusetts, Alaska, and Virginia, in that order.

Fresh water lakes and rivers of this country produce only three percent of the total. The remaining 97 percent comes from the oceans.

8.1.4 Transportation

All fish are supplied to the sardine plant by means of company boats. They move out to where fishermen have located large schools, load the fish and unload them at the plant. Other ingredients, such as oils and sauces, are brought in by truck as required.

The cans of sardines are placed in cartons and taken by truck to storage warehouses and later are again taken by truck to retail stores. Fish wastes are also moved in bulk by truck to other processing plants, where they are used to make animal foods.

8.1.5 Trends

As previously noted, per capita consumption has varied little, and the United States fishing industry is growing only at approximately the same rate as the population. The industry is, in fact, losing its share of the world market.

In 1957, the United States ranked second only to Japan as a fishing nation. Only four years later, the United States dropped to fifth place with 7.1 percent of the world catch. Japan was first with 16.3 percent, followed by Peru (12.7 percent), China Mainland, (12.2 percent), and the U.S.S.R., (7.9 percent).

There were 430 documented fishing vessels in 1961, a decline from 841 in 1950. The fleet is aging. Some trawlers are nearly 30 years old, and the average for the entire fleet is 24 years. In addition to these ocean-going vessels, are about 12,000 vessels of 5 tons and over and 65,000 small motor boats and other craft.

While the United States catch remains relatively static, the world harvest is rapidly increasing to the point where many authorities feel that stringent international regulation will soon be necessary if certain valuable species are not to be over-fished. [31]

Table 8-2 Total Catch, Salt & Fresh Water, by States, 1961

State	Quantity (x 1000 lbs)	Total (x $1000.)
Alabama	19, 820 lbs.	$ 2, 960
Alaska	413, 468	46, 470
Arkansas	6, 036	733
California	598, 438	56, 283
Connecticut	6, 142	1, 186
Delaware	304, 680	3, 743
Florida	201, 100	27, 207
Georgia	20, 532	3, 018
Hawaii	14, 472	2, 897
Illinois	6, 523	653
Indiana	1, 022	53
Iowa	3, 179	296
Kansas	60	a
Kentucky	3, 460	331
Louisiana	656, 388	22, 775
Maine	197, 970	19, 029
Maryland	66, 492	12, 778
Massachusetts	470, 774	36, 900
Michigan	24, 535	2, 931
Minnesota	15, 353	748
Mississippi	393, 883	7, 877
Missouri	374	33
Montana	17	1
Nebraska	541	39
New Hampshire	1, 146	426
New Jersey	396, 752	11, 032
New York	124, 908	9, 319
North Carolina	286, 751	6, 669
North Dakota	827	35
Ohio	15, 810	1, 398
Oklahoma	334	42
Oregon	50, 542	6, 521
Pennsylvania	1, 286	147
Rhode Island	84, 046	3, 317
South Carolina	19, 242	3, 345
South Dakota	2, 202	140
Tennessee	9, 281	998
Texas	203, 973	24, 338
Virginia	411, 414	24, 315
Washington	120, 381	18, 716
Wisconsin	32, 177	2, 492
Wyoming	378	11
Total	5, 186, 709 lbs.	$362, 210

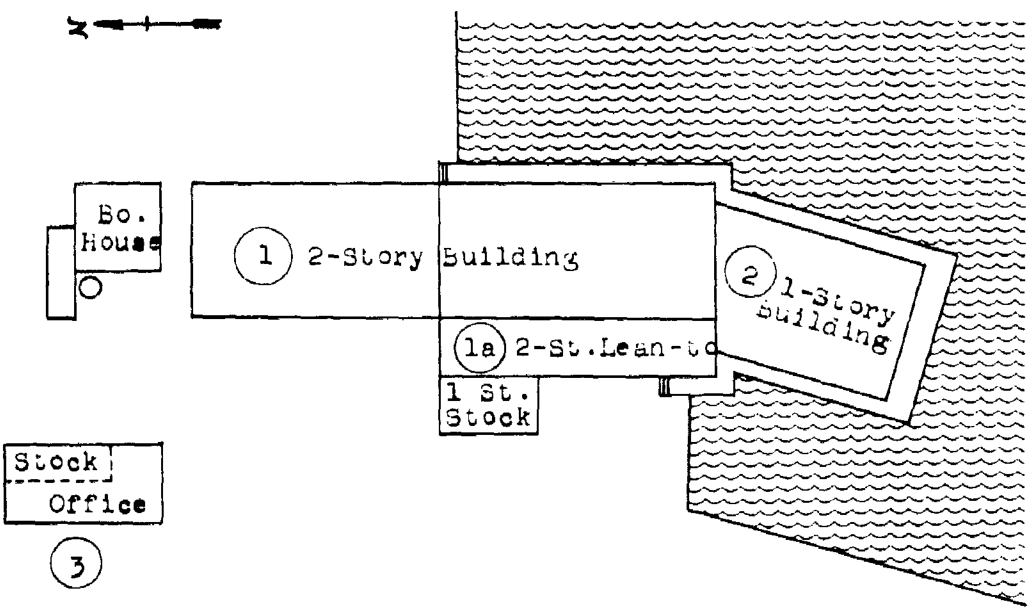
8.2 SARDINE PLANT

8.2.1 General Description

Of the nine food processing facilities studied, the sardine plant is by far the most lightly constructed, hence the most susceptible to blast damage. Except for the boilerhouse, the light construction reflects the general lack of heavy equipment in the second stories and the seasonal nature of the industry. The fishing season runs from May through October, with the result that the heavier, insulated construction necessary for operation in the cold winter months is not needed.

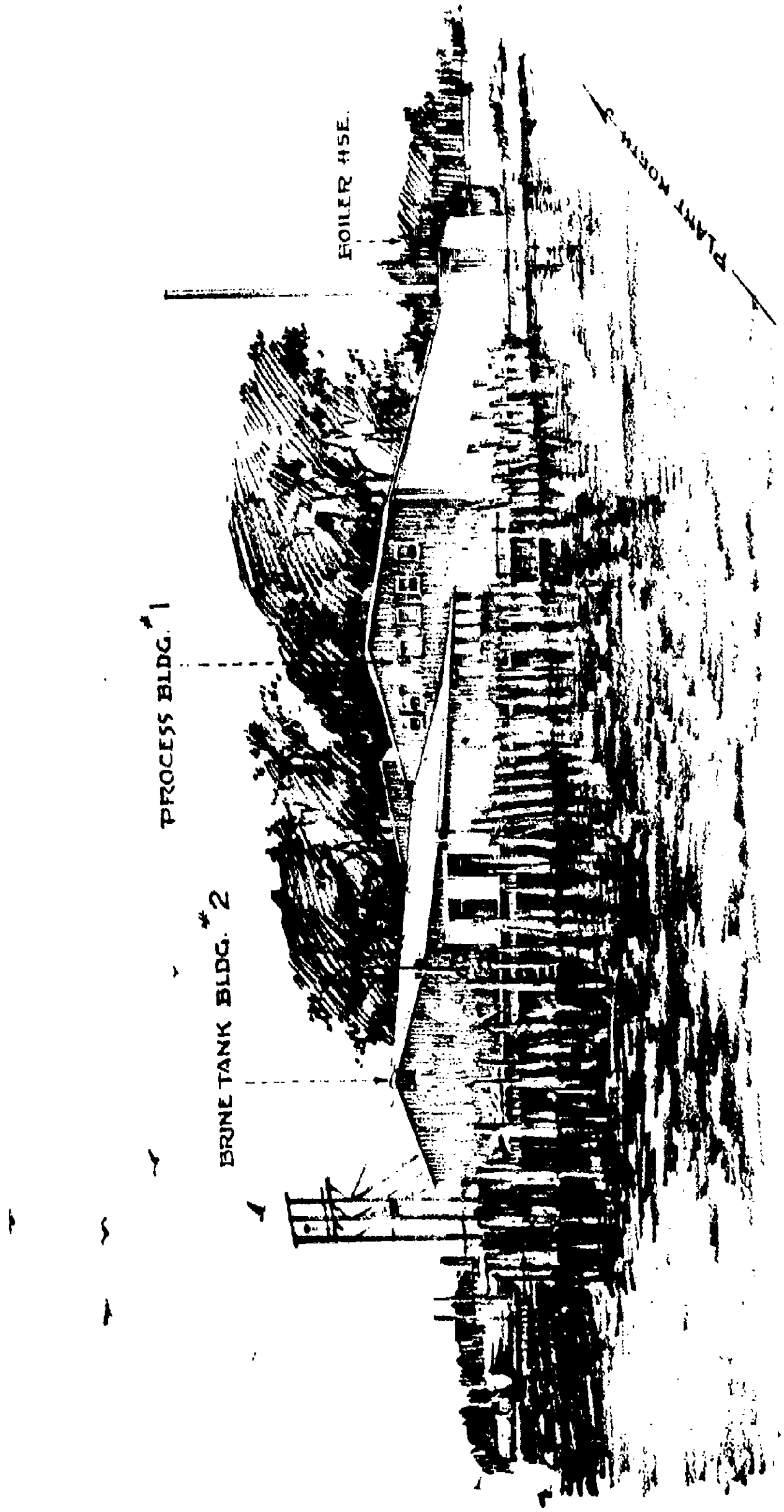
The plant and office building are of timber construction as shown in figure 8-2. The plant itself is the result of a series of additions - little more than sheds - erected to accommodate expanding production. The saddle-type roofs are covered with tar felt. All the siding on the wooden buildings is covered by red "insulbric". The boilerhouse is a one-story brick building with a small wooden lean-to at the rear; the lean-to construction is similar to that of the other wooden buildings.

A review of damage to fish plants in California and Alaska, as a result of the March 1964 Alaskan earthquake, suggests that the Maine sardine plant's construction may be fairly typical of the industry -- that is, quite vulnerable.



SARDINE PLANT LAYOUT

As shown in the sketch above, the main structure (buildings 1, 1a, and 2) is approximately 255 feet long overall. Fish are unloaded at building 2, which contains the storage cooling tanks and the brine-circulating refrigeration unit. The first floor of building 1 holds the conveyor system, 48 packing



Sardine Packing Plant

Figure 8-2

tables, steam ovens, sealing machines, retort cooker, and washer. On the second floor are the can bins and carton sealer.

The equipment is standard in type, and gives satisfactory service. The major overhauls are carried out during the winter months, and the machinery usually runs for the full production season with only a few minor repairs. The pump used for unloading fish is of centrifugal impeller design, to allow for free flow of fish through the unit without damage. The unit is of heavy-duty construction and operates without trouble over long periods of time.

The refrigeration unit is a Frick compressor which uses a 25 HP motor. This unit cools a brine solution circulated from a large reserve tank, which is open on top and is approximately 8 feet wide, 16 feet long, and 4 feet 6 inches high. The brine from this unit is also circulated to the fish tanks, as required, to maintain a temperature of 34 to 36°F.

Two large boilers supply the steam necessary for heating, washing and cooking arrangements. Each boiler is approximately 100 HP in capacity, and operates in the range of 85 to 100 PSIG. One boiler is operated exclusively on coal and is fed by a coal stoker. The coal supply normally maintained would not last more than three days. The other boiler is oil fired and fed from an outside tank supply that would last about ten days. Either boiler can be used, depending on the availability of fuel and economy of its use.

There were no apparent safety features or devices for protecting the employees from accidents, but the inherent qualities of the equipment did not appear to make for dangerous operation.

Method of Preservation

Ice is not needed to preserve the fish aboard the fishing boats, in part because of the short time lapse -- 12 hours at the most -- between loading and discharging at the cannery. The fish are heavily salted, however A typical load of 875 bushels, weighing 61,000 pounds, may call for 3,600 pounds of salt, which is shoveled over the fish as they are loaded in the hold from the nets.

Processing

Upon arrival at the cannery, the catch is unloaded into 100-bushel bins in building #2 which are kept a few degrees above freezing by means of a flow of refrigerated brine. An attendant supervises both the temperature control and the removal by trough of fish which are fed, as needed by the packers, onto a screen-belt conveyor which carries them between the rows of tables. A second conveyor, located above the first, carries a supply of cans which descend to the packers from the floor above via chutes.

The heads and tails of the fish are hand-removed at 48 packing tables, and the bodies are packed by hand into the cans; there are five, six, or eight fish per can, depending upon fish size. When filled, these tins of fish are stacked on wire trays to be removed periodically and placed on factory push-carts. The trays are loaded into a framework built onto the cart and clamped into place, with each tray resting on the tops of the layer of cans below. The framework is arranged to pivot for draining of water after the steam cooking.

When loaded, the trucks are pushed into the cookers. There are 6 cooking units in a row; each unit is 4 feet wide, 5 feet high, and 8 feet long. Pipes with a series of small holes drilled along the full length are placed along the walls and connected to the main steam supply. These jets steam the fish and cans for 40 minutes, after which they are removed to a draining area where the load is rotated on the frame axis and all water drained away. The frames are righted again, and while still on the cart, moved to a cooling and drying area for one-half to three-quarters of an hour, then brought to the unloading area where the trays are removed, placed on feed blocks, and arranged into three feed lines, one for each sealing machine. As the trays are emptied, they are placed on a conveyor which passes them through a machine which cleans them and makes them ready for reuse.

As the open cans of fish approach the sealing machines, they enter an automatic feeding mechanism which positions them at regularly controlled intervals. The sealing machine injects soy oil, mustard, tomato sauce, or whatever is called for, and lids are placed and sealed on automatically. The sealed cans are then released onto a conveyor and passed through a unit which again cleans each can. Next, they are fed onto another conveyor which brings them to four retorts. Three of these retorts hold 120 cases or 12,000 cans, and one holds 140 cases or 14,000 cans. Each retort is filled consecutively. The unit is covered tightly, and the cans are steamed at a temperature of 235°F. for 50 to 70 minutes.

The cooking time is dependent on many factors, among them the size of the fish and whether oil, mustard, or tomato sauce is used. After this cooking period is complete, water is circulated through the retort for 15 minutes, to cool the cans before removal. An attendant feeds the cans onto a belt which passes through a final washing unit, where strong soaps are used to take off any remaining oil and dirt. A final steam jet sprays the cans as they leave the washer to make them spotlessly clean. They are then fed onto another conveyor, which takes them up to the second floor and feeds them into large bins to cool and dry thoroughly before packing. Fifty to one hundred cans are hand-packed in each carton, placed on a conveyor belt, passed through a sealing machine, and sent on to be loaded into a waiting truck and transported to a warehouse.

8.2.3 Personnel (normal)

The following personnel operate the plant and boats:

Office personnel	4
Fishermen (on boats)	4
Packers (women)	100
Material handlers	7
Machine operators	3
Maintenance	2
Shipping	5
Total	125

This plant works on a single shift basis through June, July, August and September. Some preparation work starts in May, and shutdown work in October, but for the remainder of the year the only personnel around the plant are the office staff, the captain of the boat and the maintenance crews who overhaul equipment and prepare for the next season's operation.

8.2.4 Shelter (within plant)

The sardine plant has no fallout shelter arrangement. The facilities and location do not lend themselves to this protection, from a practical, economical point of view. The best solution is for the plant personnel to shut down all equipment and leave as fast as possible to seek shelter at home or elsewhere in the community.

8.2.5 Shutdown and startup (normal)

Shutdown and startup are daily routines. At the end of each day all equipment is hosed down with fresh water in order to remove all traces of fish. At the end of the fishing season in October, processing is discontinued until startup in May. Startup is also routine.

8.2.6 Utilities (normal)

Electric power

Electric power is supplied to the plant over a wooden pole line which is part of the Rockland City power system. Three separate transformers step the three-phase power down to the required voltages to operate the motors, lights, and communications. The total operation of the present facilities would not require more than 75 KVA at the most.

Water supply

Fresh water is supplied from the city for domestic use, for washing and cleaning the fish, for the boiler water and sprinkler system. The fire sprinkler system is modern and well planned.

8.2.7 Repair and maintenance capability (normal)

The plant equipment is of good quality and presents few maintenance problems. Most maintenance is handled in a leisurely fashion during the winter months, when the plant is not operating, by the general foreman, the sealer machine foreman, and the company boat captain. They are assisted by a half dozen part-time workers, who are retained as needed.

The operating personnel consist of 100 women packers and 25 men who operate the equipment. Because of their familiarity with the equipment, the men could be used to augment the regular maintenance force in an emergency repair situation.

8.3 VULNERABILITY ANALYSIS

8.3.1 Low pressure blast range (0.0 psi to 1.2 psi)

Within this range, low pressure shock waves will affect the complete area. Any blast that develops a pressure of 1.0 psi at the plant will tend to crack the windows, and blast pressure that reaches 0.5 psi will probably shatter all glass and some window frames. Window frame failures, starting at 0.1 psi would be more or less complete by 0.5 psi.

Below 0.1 psi, fallout will be the only hazard to account for, but as the pressure reaches 0.5 psi, glass will start to fly, driving into equipment and spreading throughout all areas. This missile damage will increase as the pressure increases up to the point of collapse of the buildings, which will start at approximately 1.2 psi.

8.3.2 Medium pressure blast range (1.2 psi to 3.0 psi)

Within this medium range, damage by flying glass will increase considerably. At 1.2 psi, the wall on the first floor of the process building will fail, causing the collapse of the entire structure and damaging all the facilities contained within. At the same overpressure, the office and stock building will collapse and the building that houses fish and refrigeration tanks will also collapse. This means the entire process system, as well as office space, will be completely demolished and inoperative. The only building remaining intact at this pressure will be the boilerhouse, which may show some cracking at 1.3 psi in the east wall. This cracking would increase with higher pressures, but the wall probably would not collapse during this range. The roof beams may fail at 2.7 psi, causing roofing material to fall on equipment and boilers. Communication equipment in the office would be severely damaged. Figure 8-3 illustrates the condition of the plant at 1.5 psi overpressure if no fire develops. Fire is discussed in section 8.3.4.

8.3.3 High pressure blast range (3.0 psi to 6.0 psi)

Near 3.0 psi overpressure, collapse of the structures will be general except for the boilerhouse, which may still be intact except for the roof beams. At 3.0 psi, roof beams will yield, resulting in varying degrees of damage, but total collapse of the building might not take place until ground 4.0 psi to 6.0 psi. However, if the blast were from the east, the east wall would fail, resulting in the complete collapse of the boilerhouse at 3.0 psi.

8.3.4 Fire hazard

Of all the plants studied in this report, the wooden construction of the sardine plant, which is typical of the fishing industry, is the most vulnerable to fire. This is unique to this industry in that it can easily cause total plant destruction and it is therefore discussed separately.

If power lines remain intact, as they generally do up to about 4.0 psi, and electricity is not shut off at the power source, the fire hazard will be high due to

Fire at Sardine Packing Plant Beyond 1.2 psi Overpressure

Figure 8-3

the possibility of short circuits in the power line at any point from where it enters the building, to the fuse box. In terms of fire, the upper limit of the high range is no longer 6.0 psi as indicated in section 8.3.3 but 1.2 psi which, without fire, is the lower limit of the medium range as indicated in section 8.3.2. Figure 8-4 illustrates the complete destruction of the plant at 1.2 psi from blast effects and subsequent fires.

The combination of blast damage and fire obviously reduces the categories of damage from three ranges to one range, with the estimated level of effort of repairing the plant also changing. The limits of damage would range from overpressures of 0.0 psi to 1.2 psi. The damage incurred in this range would be the same as that in section 8.3.1 up to an overpressure of 1.2 psi, at which time fire could begin and completely destroy the plant and its equipment assuming, of course, that electric power had not been shut off at its source.

8.3.5 Thermal radiation

Because there is very little material around the plant which could be easily kindled by a thermal flash, it is unlikely that anything other than charring would result from thermal radiation.

8.3.6 Fallout

Fallout on and around the frame buildings, whose protection factor would be two or less, would constitute a most dangerous situation for personnel in the cannery's processing buildings. Fallout could accumulate on the roofs, on the walkways, on the barrels of mustard, tomato sauce, and soy bean oil stored outside, and on the ground adjacent to the buildings; on the east (seaward) side, however, fallout would land on the water, sink to the bottom, and have no effect on personnel.

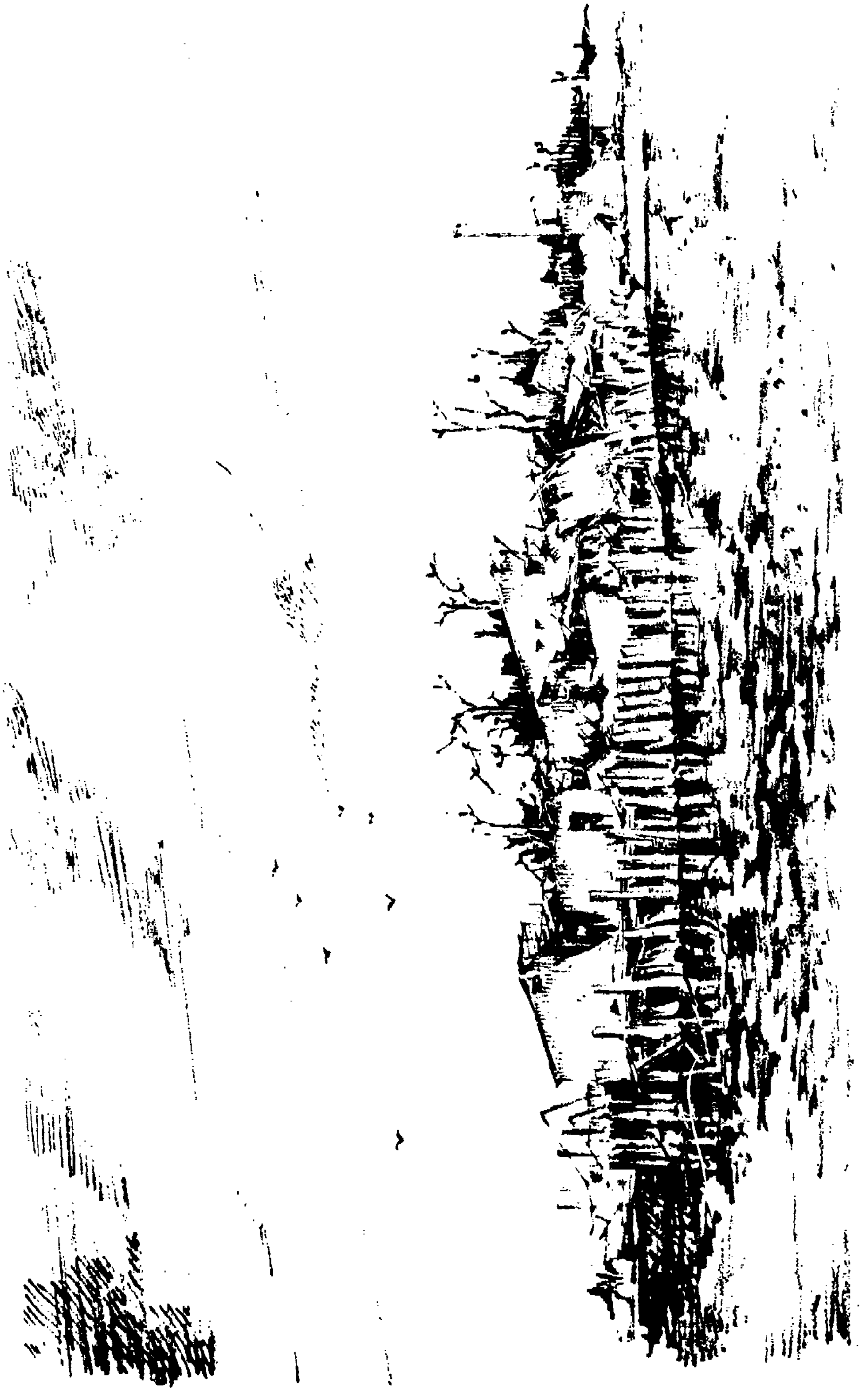
8.3.7 Shutdown

There is virtually no shutdown problem. The boilers are self-regulating and, if panic precluded their being shut off, the fires would go out when the coal and/or oil supplies were exhausted. If fish were left to decay, the results would be unpleasant but would present only a minor cleanup problem.

As soon as conditions permitted, fallout would have to be carefully removed from the affected areas with water hoses and particular care should be paid to the sauce and oil barrels. Startup would also involve cleaning any areas such as the cooking retorts or conveyors which the rotted fish might have contaminated. Then the boilers should be checked, and the power turned on.

8.3.8 Bottlenecks and weak links

Many of the weak links of the sardine fishery apply to the fishing industry as a whole. The factories generally are of light construction, are built on the water, and are therefore highly vulnerable to blast and to tsunami damage as well.



Damage to Sardine Packing Plant at 1.5 psi Overpressure

Figure 8-4

With the exception of sardine boats and certain large Pacific coast tuna clippers, which use salt and refrigeration, respectively, ice is vital to shipboard preservation of fish; fishing on the present scale would be impossible without it. Typically, there is one ice plant, electrically operated, per fishing port, and it is logical to assume that in most cases destruction of the ice plant would be accompanied by destruction of the cannery. If either one were destroyed or heavily damaged, any surviving fishing vessels would have to transfer operations to an undamaged port.

The essential weak links are the structures themselves. As was shown in section 8.3.2, major damage occurs to the cannery at relatively low levels of overpressure. The process building is heavily damaged at 1.2 psi, and destruction of all structures, except for the boilerhouse, is virtually complete at 1.5 psi. Fires, if they occur, would lower the level still further.

Potential bottlenecks include such essential equipment as the conveyors, cooking ovens, sealing machines, retort cookers, and the refrigeration system. However, it seems apparent that, during the period of time necessary for clearing away and rebuilding the structures, these units could be repaired, rebuilt, or parts could be cannibalized from machinery in the plant or elsewhere.

The requirements for diesel fuel and salt in the fishing operation are obvious. On the other hand, the sardine industry is set apart from most other types of fishing operations in that it does not use ice. This could be a considerable advantage in case an attack damaged artificial ice plants or the electrical inputs without which the ice plants could not operate. Salt is, of course, necessary for the shipboard preservation of sardines and could conceivably be a weak link, but the problem does not compare with that of ice.

Finally, the danger of destruction by tsunami action should be noted, particularly in view of the recent experiences in Alaska and California. Because the cannery is located in a cove, the onrushing wall of water would be constricted and the wave height increased.

8.4 RECOVERY

8.4.1 Summary of damage

Summaries of damage to structures and processing equipment are found in tables 8-3 and 8-4, respectively.

8.4.2 Spare parts and cannibalization

There are very few spare parts stocked. If parts are needed they are ordered from the firms manufacturing them.

Cannibalization within the plant is limited to the steam cookers, the can sealing machines, and possibly the conveyor systems. Salvagability of the last-named will depend upon the extent of damage. Otherwise, there would have to be exchanges of equipment with other plants in the area.

8.4.3 Initiating emergency operation

Operation following low blast damage (0.0 psi to 1.2 psi)

The minimum time requirement to initiate emergency operation of the facility after blast effect in the low range may be about 50 man-days to start operations. The major effort will be directed at cleaning up of dust, dirt and debris within the process building. All machinery will have to be cleaned and checked for flying glass. All fish exposed to dirt and flying glass will have to be discarded.

If fires occurred as described in section 8.3.4, the upper limit would include an overpressure of 1.2 psi. The plant would then be destroyed and no emergency operation could be started.

Operation following medium blast damage (1.2 psi to 3.0 psi)

Extensive damage to structures in this range will require the removal of debris from the collapse of the processing plant and the erection of temporary cover. Steam cookers and sealing machines could be cannibalized in an effort to produce at least one piece of equipment of each and the fish could be manually carried through the processing system to circumvent the need for conveyors for the time being.

The boilerhouse roof need not be repaired at this time but the debris will have to be cleared away and all controls, gauges, piping and boilers would require cleaning and repairing.

Operation following high blast damage (3.0 psi to 6.0 psi)

In the high range the primary concern is with efforts to restore the production of steam in the boilerhouse, because steam is of prime importance to the processing of fish.

The repair and possible replacement of boilerhouse equipment would be in addition to that required in the low and medium ranges. All debris caused by pressure in this range would have to be cleared away.

Table 8-3 Summary of Damage to Structures

Overpressure psi	Bldg.* #1	Bldg.* #2	Bldg. #3	Boilerhouse Walls
0.1	Glass Cracks	Glass Cracks	Glass Cracks	Glass Cracks
0.5	Glazing Shatters	Glazing Shatters	Glazing Shatters	Glazing Shatters
1.2	Frame and Walls Collapse	Frame and Walls Collapse	Walls Fail Bldg. Collapse	East Walls Crack
2.7				Roof Beams Fail
3.0				East Walls Fail
6.0				Roof Girders and Walls Collapse

*If fires occur as stated in section 8.3.4, the damage to buildings No. 1 and 2 would be complete destruction after an overpressure of 1.2 psi.

Table 8-4 Summary of Damage to Processing Equipment

Structural	Critical Overpressure	Processing Equipment
Glass cracks	0.1	Dust and fallout throughout plant.
Glazing shatters	0.5	Glass missile damage to equipment.
Bldg. #1 & #2 frames & walls collapse	1.2	Conveyors, sorting tables, retorts, sealers, packaging equipment.
Bldg. #3, frame & walls collapse		Office equipment and parts supplies damaged.
Boilerhouse, east wall cracks		Some missile damage to piping and gauges.
Boilerhouse, roof beams fail	2.7	Damage to boilers and piping.
Boilerhouse, east walls fail	3.0	Piping and pumps damaged.
Boilerhouse roof girders & walls collapse	6.0	Boilers and all auxiliary equipment damaged.

8.4.4 Shortcuts

There are few opportunities for shortcuts in the processing system, because competition has forced handling operations down to the bare minimum. The steam cooking, sealing and reheating of the cans are necessary operations. The cutting off of heads and tails is necessary to fit the fish in the cans, and the canning machines can handle no other sizes of cans. The only phases of the system which could be eliminated are the injection of oil, mustard or tomato sauce prior to can sealing and the cooling of the cans after reheating by packaging almost immediately.

8.4.5 Utilities

Electric power

Electric power is essential to the operation of the plant equipment. Above 4.0 psi, when transmission poles are blown down, startup will be delayed unless auxiliary power of the mobile type is brought in.

Water supply

Piping within the plant is vulnerable. It could break or joints could loosen, so that water is released when the buildings collapse. Otherwise, the mains are deep underground and are considered safe.

8.4.6 Repair required to resume normal operation

Low blast pressure range

Up to 1.2 psi, much cleaning time and effort will be required to remove all broken glass scattered throughout the processing area, where fish may be exposed. It will be necessary to clean carefully all cold storage tanks, troughs, conveyors, packing tables and equipment, and all containers used to handle sardines before they reach processing machinery.

This cleaning of the processing area will require approximately 50 man-days before fresh fish can be handled again. The rest of the plant area will need cleaning, but operations will not be delayed beyond this requirement. Flying glass might damage some of the pressure and temperature gauges, and replacement will be required. If these were on hand, replacement could be made within four or five days, by regular operators in the plant. If all the glazing is shattered with missile damage to equipment, it will take another 100 man-days to repair equipment and replace parts as needed for complete recovery.

The total work, then, would be 200 man-days, and could commence at any time after the fallout hazard had reduced to a safe point.

Medium blast pressure range

The major effort in this range involves the repair of the main building failures. Buildings #1 and #2, which contain the entire processing system, will have to be rebuilt as will the office and stock buildings. Much of the equipment with the exception of the can sealers would require extensive repairs or replacing. The can sealers are of rugged construction and would probably require only checking and minor repairs. The east wall of the boilerhouse would require repointing.

Labor would be required for cleanup, tradesmen for repair work, and technicians to supervise, check and test the boilers before they could be used again. The use of metal cabinets or screens prior to attack as protection for meters and glass gauges could save equipment, particularly the glass water level gauges on the boilers.

Communication equipment in the office would need replacement. Transformers and power supply would be damaged or out of order and would need checking, remounting and new connections.

The repair effort in this range is contingent on the fact that no fires break out from shorted wiring. If there was a fire then the plant would be damaged beyond economically feasible repair.

High blast pressure range

In addition to the repair required in the low and medium ranges the following effort will be necessary.

At 3.0 psi, the collapsed boilerhouse will require repairing and up to 6.0 psi, it may be economical to repair it and its equipment. At 6.0 psi, the entire plant will be demolished and possibly burned to the point where it would require complete rebuilding.

8.4.7 Substitutes

Any nonperishable, relatively inexpensive source of protein will serve as a substitute for sardines. Among many possibilities are other canned fish such as tuna and salmon, canned meats, powdered milk, soy beans, and even wheat and wheat flour. Conversely, the Maine sardine industry, at its current operating rate could supply the entire postattack protein needs for 1/4 to 1/2 million people.[2, 17, 25]

8.4.8 Increased production capability

Production could be increased by working "around the clock" instead of the usual one shift. Extra boats, if available in the postattack period, could be used to increase the supply of fresh fish. This could well be the case if a plant were destroyed while the boats that normally supply its fish were out at sea. Plans to increase production are hypothetical at best, however, because of the unpredictability of the catch even under normal circumstances.

8.4.9 Estimated man-days required for each level of blast pressure

Estimates of the effort required to repair the plant in the low, medium and high ranges of blast damage are found in the following charts. Immediately following these charts is the Recovery Chart, figure 8-5, which illustrates graphically the repair time as listed in the repair estimates.

SARDINE PLANT

Low Blast Damage Range 0.0 to 1.2 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
0.1	glass cracking	clean up dust, dirt & debris	labor	10	5	50
0.5	glazing shattered	clean up and replace all windows	labor	10	5	50
			Structural			100
	PROCESS					
0.1	glass cracking	clean up equipment	labor	10	5	50
0.5	glazing shattered	clean, check & repair from missile damage	labor	10	5	50
			Process			100
			Structural			100
		Total Man-Days for Low Range				200

Note: In the event fires occurred at 1.2 psi which is the lower limit of the medium range then the repair requirement up to 1.2 psi is as shown above. At 1.2 psi or above, it would not be economical to repair the plant.

SARDINE PLANT

Low Blast Damage Range 0.0 to 1.2 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
	Clean up dust and debris			5	5	25
	Process					
	Clean, check and repair equipment			5	5	25
		Total Man-Days for Low Range				50
	Note: See note on chart on page 8-23.					

SARDINE PLANT

Medium Blast Damage Range 1.2 to 3.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
1.2	#1 bldg. frame and walls collapse	clean up and rebuild	labor tradesmen	50	30	1,500
1.3	#2 and #3 bldgs. frame and walls collapse	clean up area and rebuild	labor tradesmen	30	30	900
	boilerhouse east wall cracking	clean up, check and repair	labor tradesmen	10	30	300
2.7	boilerhouse roof beam fail	clean up and repair	labor tradesmen	10	30	300
			Structural			3,000
	PROCESS					
1.2	#1 bldg. frame and walls collapse	clean up, repair and replace damaged equip.	labor tradesmen technicians	50	30	1,500
1.3	#2 & #3 bldgs. frames and walls collapse	clean up, repair and replace damaged equipment	labor tradesmen technicians	20	30	600
	boilerhouse east wall cracking	clean up, check equipment repair and replace	labor tradesmen technicians	5	30	150
2.7	boilerhouse roof beam failure	clean up, check boilers and equipment, repair and replace	labor tradesmen technicians	5	30	150
			Process			2,400
			Structural			3,000
		Total for 1.2 psi to 3.0 psi				5,400
		Total for Low Range				200
		Total Man-Days for Medium Range				5,600

SARDINE PLANT

Medium Blast Damage Range 1.2 to 3.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	Structural					
1.2	clean debris from #1 building			12	25	300
1.3	clean debris from #2 building			3	25	200
.	clean debris from boilerhouse			2	25	50
2.7	clean roof debris from boilerhouse			2	25	50
	Process					
1.2	clean up equipment. repair and replace damaged parts in building #1 cannibalize steam ovens and sealing machines			12	25	300
1.3	clean up and repair refrigeration unit and the storage cooling tanks in building #2			4	25	100
	clean and check equipment and controls at boilerhouse			4	25	100
2.7	check and repair boilers. repair and replace meters, gauges, and controls, repair damaged steam piping			4	25	100
		Total for 1.2 psi to 3.0 psi				1,200
		Total for Low Range				50
		Total Man-Days for Medium Range				1,250

SARDINE PLANT

High Blast Damage Range 3.0 to 6.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	STRUCTURAL					
3.0	boilerhouse east wall fails	clean up and rebuild wall	labor tradesmen	10	30	300
5.0	boilerhouse roof girders fail	clean up and repair roof	labor tradesmen	10	30	300
			Structural			600
	NOTE: At or above 6.0 psi it is no longer economical to repair the plant					
6.0	boilerhouse walls and frame collapse	rebuild				
	PROCESS					
3.0	boilerhouse east wall fails	clean up and repair equipment	labor tradesmen technicians	10	30	300
5.0	boilerhouse roof girders fail	clean up equipment - check boilers - repair & replace parts	labor tradesmen technicians	10	30	300
			Process			600
			Structural			600
		Total for 3.0 psi to 6.0 psi				1 200
		Total for Medium Range				5, 600
		Total Man-Days for High Range				5, 800

SARDINE PLANT

High Blast Damage Range 3.0 to 6.0 psi

Pressure Range (psi)	Damage	Work Required	Type of Personnel	Repair		
				Men	Days	Man-Days
	MINIMUM REQUIREMENTS FOR EMERGENCY OPERATION					
	<u>Structural</u>					
3.0	clean up debris of collapsed east wall of boilerhouse			4	25	100
	<u>Process</u>					
3.0	clean equipment and repair or replace meters and controls. repair piping and boilers			8	25	200
		Total for 3.0 to 6.0 psi				300
		Total for Medium Range				1,250
		Total Man-Days for High Range				1,550

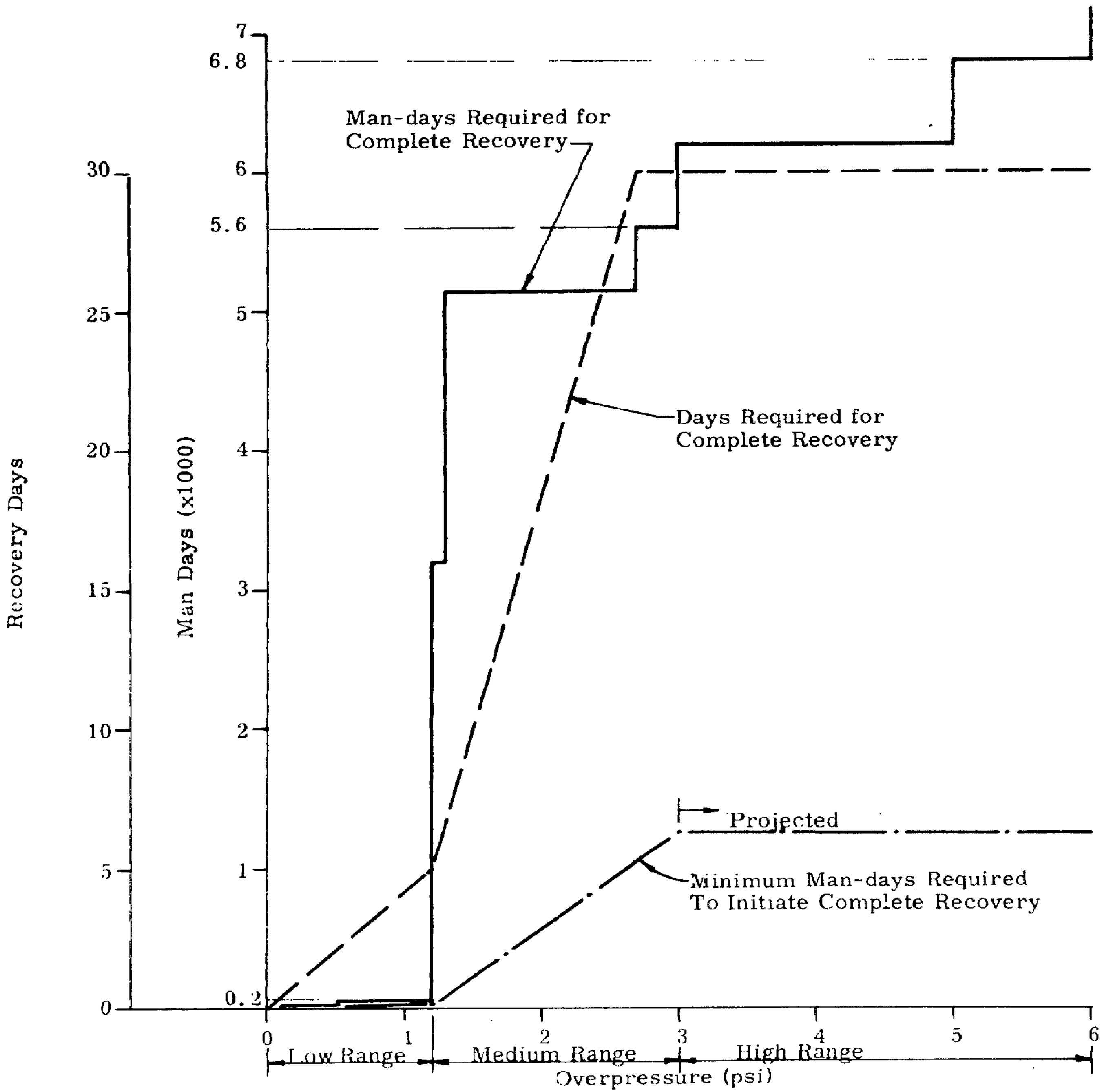


Figure 8-5 Recovery Chart - Sardine Plant

8.5 CONCLUSIONS

The sardine industry was studied partly because the canned fish would be an ideal food in the wake of an attack. Canned food needs no refrigeration; also, food from the ocean in a later postattack period would probably not be seriously affected by fallout contamination. Sardines were also studied as being representative of the United States fishing industry.

Because of light, chiefly wooden construction, the sardine plant is easily the most blast-vulnerable structure covered in this study. Fire is also a hazard, since the collapse of the building, causing short circuits, could occur before the power lines go down, in which case nearly complete destruction could occur at 1.2 psi. Damage ranges: low 0.0-1.2; medium, 1.2-3.0; high, 3.0-6.0. Aside from the weak structure, there is another "weak link": the unpredictability of the catch of fish.

9. MEAT INDUSTRY

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9. MEAT INDUSTRY

9.1 INTRODUCTION

Because of the widely-scattered diversification both of cattle and of the more than 3,000 meat packing plants, which generally are located well away from urban concentrations, the meat industry as such is not particularly vulnerable to attack, hence not within the scope of the present Critical Industry Repair Analysis. However, the essentiality of meat in the diet, and its perishability, prompted an interview with Dr. Herrell DeGraff, president of the American Meat Institute. As a spokesman for the industry, Dr. DeGraff evinced considerable concern for the postattack period, particularly in the critical area of transportation.

The following is an outgrowth of this discussion plus a limited amount of research, and points to the need for further study in the critical area of the relationship between food and transportation, and between transportation and petroleum, of which the following analysis admittedly merely scratches the surface. It should not be construed, then, as a study in any way comparable, either in intention or in scope, to that of the seven studies which have preceded it.

9.2 NUMBER AND DISTRIBUTION OF PLANTS

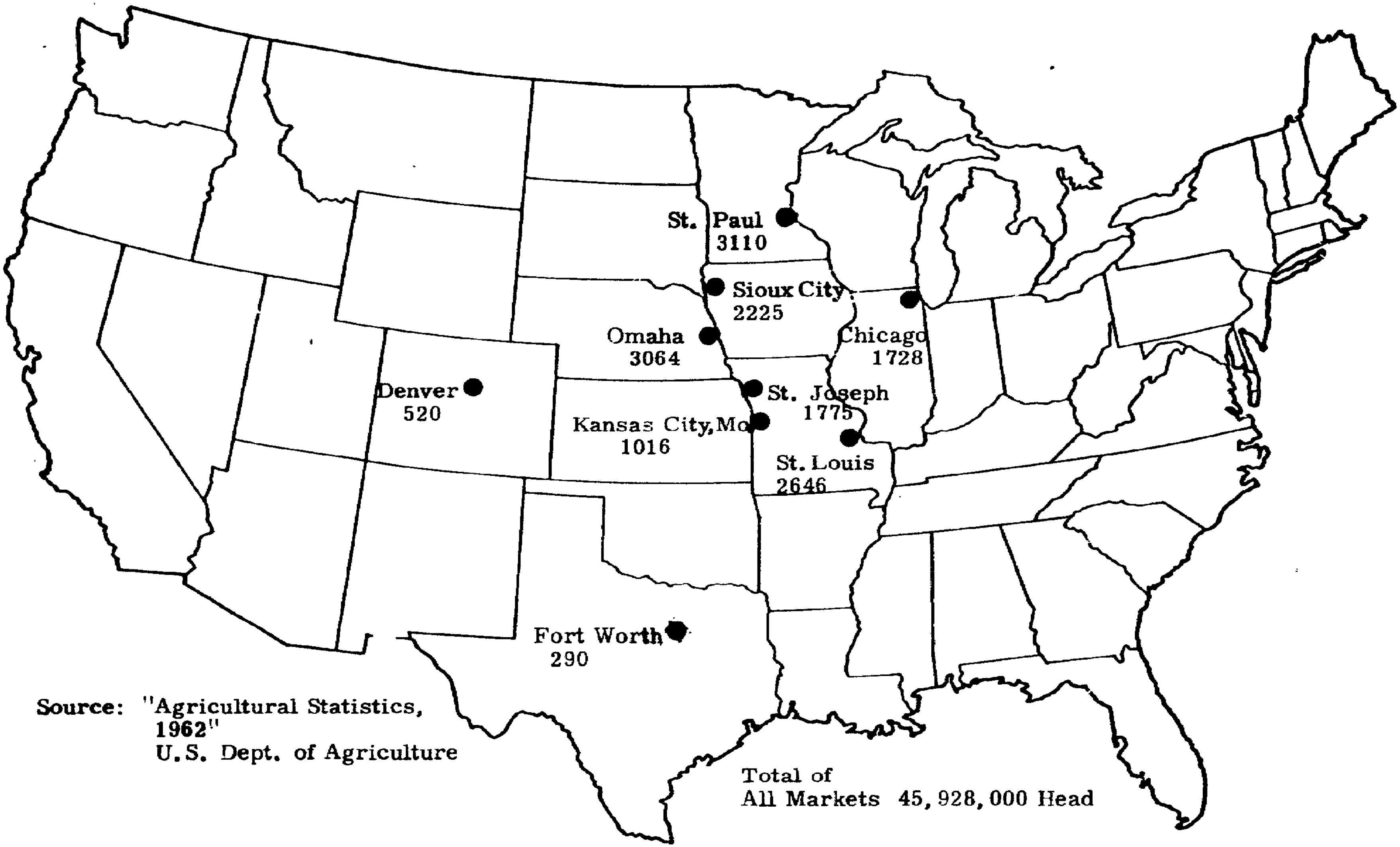
Approximately 1,500 packing plants, or about half the total number, handle 80 percent of the volume of meat processed. While they are distributed throughout the United States, the heaviest density is in Iowa where there are over 100 plants. Approximately two-thirds of the cattle come from the Corn Belt as do 80% of the hogs, with the remaining third of the cattle coming from the far west, as shown in figures 9-1, 9-2 and 9-3.

9.2.1 Plant sizes and production capacity

There are about 30,000 people employed in the industry. A recent trend in the industry has been to smaller decentralized plants. The average plant may process approximately 5,000 head of cattle per week using 90 people in a 48-hour week. Slaughtering of animals takes approximately one man-hour per head, with an additional one-half hour required for "breaking time", in which the carcass is reduced to wholesale cuts. Processing of wholesale cuts into retail cuts can be done at the rate of approximately 60 lbs. per hour, requiring 9 to 10 hours for a steer averaging 600 lbs.

9.3 TECHNOLOGICAL DEVELOPMENTS AND TRENDS

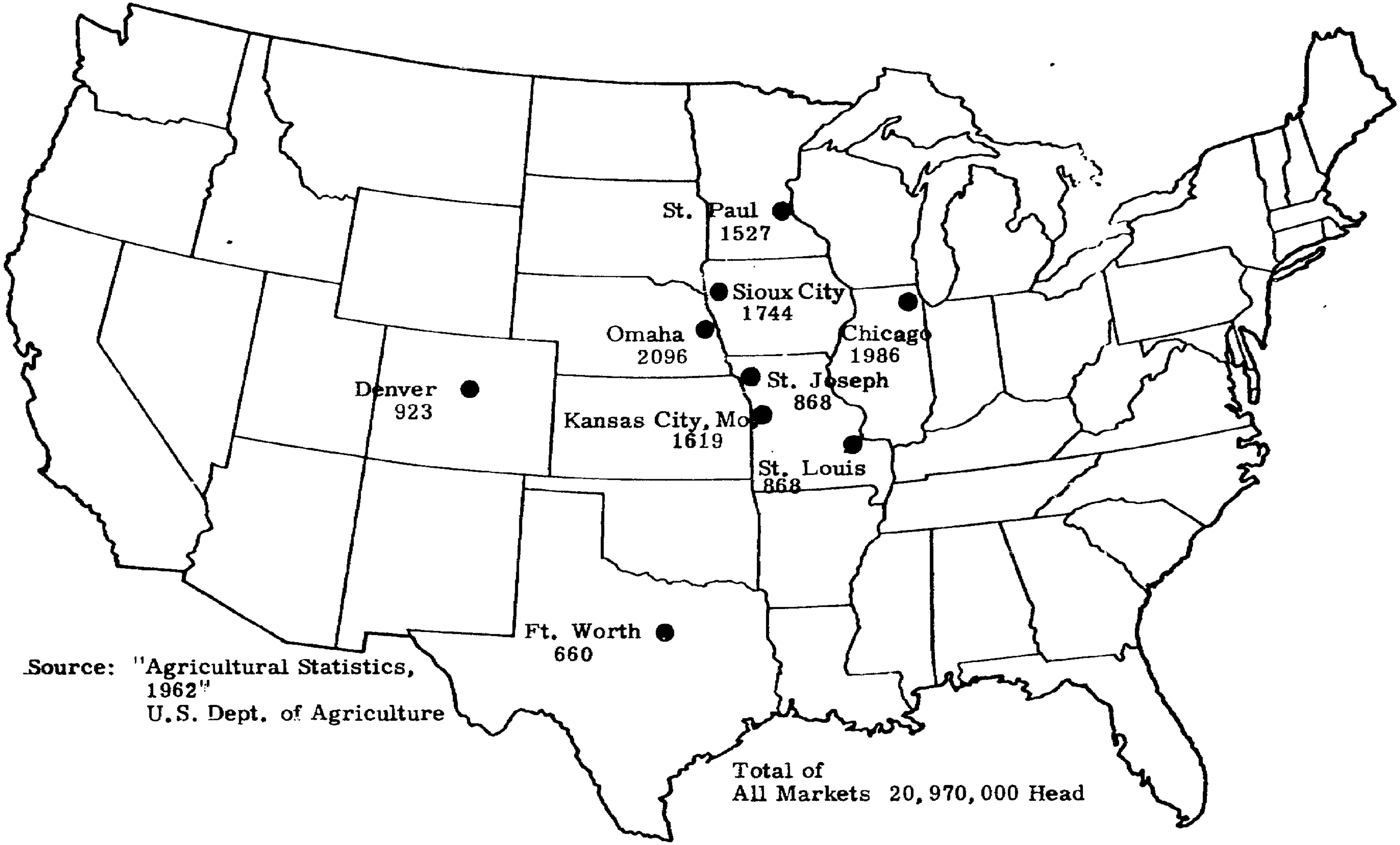
There are approximately 50 new plants constructed each year. The trend to this construction of smaller, decentralized plants is due to several factors, of which the primary one is the proliferation of refrigerated trucks and railroad cars. Meat no longer has to be shipped "on the hoof" to a central processing plant in a congested city. In addition to the space and weight saving, further economies result from the self-evident fact that butchered meat need not be fed on the way to markets. Another factor is lower labor costs.



Source: "Agricultural Statistics, 1962"
U.S. Dept. of Agriculture

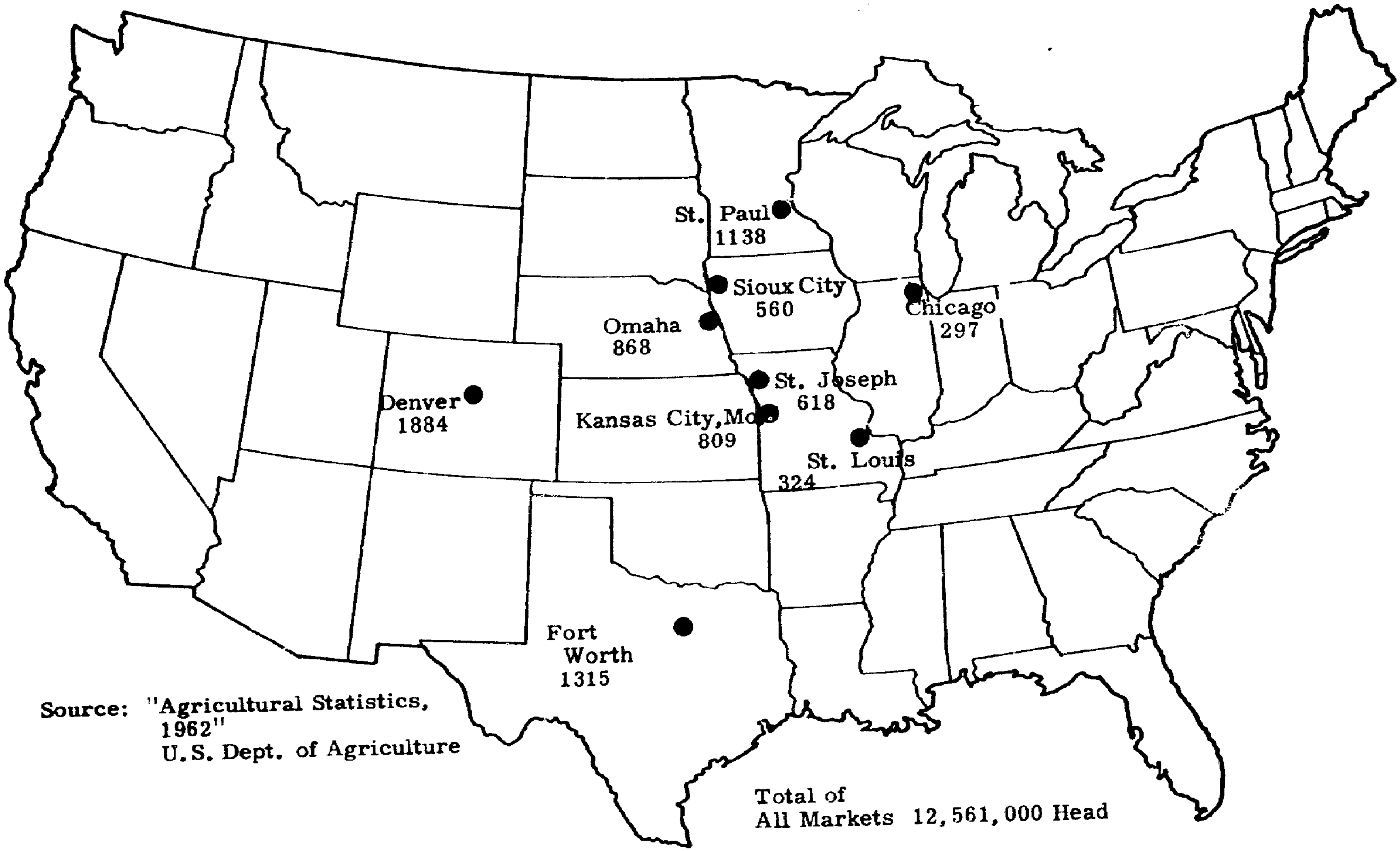
Total of
All Markets 45,928,000 Head

Figure 9-1 Hogs - Receipts at Public Stockyards, 1961
(Thousand Head)



Source: "Agricultural Statistics, 1962" U.S. Dept. of Agriculture

Figure 9-2 Cattle & Calves - Receipts at Public Stockyards, 1961
(Thousand Head)



Source: "Agricultural Statistics, 1962"
U.S. Dept. of Agriculture

Figure 9-3 Sheep & Lambs - Receipts at Public Stockyards, 1961
(Thousand Head)

Labor in rural areas can amount to $1.00 to $1.25 per hour less than in the cities. Also, the decreasing importance of pharmaceuticals as byproducts of meat packing, because these products are now synthesized, has caused packing plants to drop this function, with the result that the plants are smaller and more specialized. Lastly, the development of the chain stores, both retail and cooperative, provides many additional local customers for local packing houses. The current practice is to ship beef in "sides" (half carcasses) most of which is never frozen, to the chain stores where they are broken up into retail cuts.

This trend toward decentralization runs, of course, contrary to the general trend toward centralization in almost all other segments of the food industry. It is an obvious asset in the postattack context.

9.3.1 Future developments

There are a few technological developments which could affect the industry in the near future. One which could produce a major change would be the increased usage by the public of frozen meat. This is perfectly possible and within current technological capabilities, but it has not yet achieved sufficiently wide public acceptance to be a major factor. Of the 161 lbs. of meat per person consumed annually in the United States, only 10 lbs. is frozen. While there are approximately 13,000,000 home freezers in use in this country, constituting a good market, at present there is no real economic advantage to the public in buying frozen meat instead of fresh meat through local stores.

Freeze drying costs about 7 cents per pound of moisture removed, which is prohibitive. Radiation sterilization of meat is not currently practical for most meats, because flavor and texture are adversely affected. A recent breakthrough, however, has lead to the acceptance of irradiated bacon in the Army Materiel Command. Either development could be quite advantageous to postattack recovery in providing an inventory of meat not requiring refrigeration.

9.4 MEAT SUPPLY IN POSTATTACK PERIOD

The following analysis of the meat supply in the postattack period was made for the northeast area of the United States. This area was selected because locally-produced livestock is negligible in the megalopolis.

In the state of New York, there is a total refrigerated warehouse volume, comprised of public and private cold storage and meat packing establishments, of 94,064,000 cubic feet.[4] Assuming five pounds of hung meat occupies a space of 1 cubic foot, which allows room for the proper flow of refrigerated air and the space occupied by aisles, the storage capacity in terms of weight becomes 470,320,000 lbs. or 325,160 tons.[2]

Using the average yearly meat consumption rate of 161 lbs. per person or 13.4 lbs. per person per month[23], the maximum time required for the complete consumption of stored meat in the state of New York with a population of 16,782,000 is two months.

To stock these warehouses with meat for a two-month period from a supply in Chicago, 850 miles from New York City, would require approximately 11,760 refrigerated truckloads with each truck having a capacity of 20 tons. On a round trip distance of 1,700 miles, the 11,760 truckloads represent about 20 million truck miles. At a fuel consumption of diesel oil of 10 miles per gallon, the amount of fuel required would be 2 million gallons.

The factor which limits the time during which a refrigerated truck is effective is, of course, the refrigeration unit. The most popular unit in the United States is a gasoline-operated compressor with a fuel consumption of 1/2 gallon per hour. With tank capacities ranging from 30 to 50 gallons, the maximum running time would be 60 to 100 hours. The unit runs approximately one hour out of every two hours to maintain proper temperatures, which means that the fuel is consumed at a rate of 6 gallons per day or 18 gallons per truck over the three-day traveling period. This results in a total refrigeration fuel consumption for 11,760 truck loads of 211,680 gallons of gasoline, or roughly one-tenth the transportation fuel requirement.

Thus, the factors involved in supplying meat to the State of New York are as follows:

1)	Cold storage capacity (volume)	94,064,000 cu. ft.
2)	Cold storage capacity (weight)	235,160 tons
3)	Duration of supply based on a one-time stocking of warehouses	2 months
4)	Refrigerated truck loads	11,760
5)	Diesel oil required for trucks	2,000,000 gallons
6)	Gasoline for truck refrigeration	211,680 gallons
7)	Spare parts and tires would also be a factor of a certain magnitude which has not been determined in this report to date.	

It should be kept in mind, however, that the above figures are based on (1) a peacetime consumption rate which could doubtless be reduced in a postattack crisis, (2) an existing refrigerated storage capacity which could be increased by the use of refrigerated trucks (provided there was a surplus of trucks), and (3) the non-use of livestock produced within the state.

If livestock produced within the state were processed, the quantity would be so small, (9550 tons per month) in comparison to that required, that it could not be considered as significantly reducing the truck loads or fuel consumption.

The important fact is that the above analysis was made for one state and one food product. It is self-evident that the stored supply of meat is below the minimum standard requiring a minimum supply of three months, and that all of the warehouse space cannot be used for meat alone when other food products requiring refrigeration are necessary for survival.

If this analysis is projected to include the northeastern states of New England, New York, Pennsylvania, New Jersey, Delaware, Maryland, and Washington, D.C., using the same assumptions as before, the following data result:

1)	Population	48,989,000
2)	Cold storage capacity (volume)	232,948,000 cu. ft.
3)	Cold storage capacity (weight)	582,370 tons
4)	Duration of supply based on a one-time stocking of warehouses	1.8 months
5)	Refrigerated truck loads	29,120
6)	Diesel oil required for trucks	4,950,000 gallons
7)	Gasoline for truck refrigeration	524,000 gallons

Here again, the warehouse supply based upon a one-time stocking is below requirements and livestock production within the area is too small (34,300 tons per month or about 10% of the monthly consumption) to consider any reductions in long distance truck loads.

9.4.1 Supplementary cold storage

To supplement this lack of storage space, refrigerated trucks could be used if there were enough of them not required for the transportation of other foods. Each trailer truck has a capacity of 20 tons; therefore, approximately 19,680 trucks would be required to create the needed additional storage for a three months supply for the east coast megalopolis.

It is clear from this analysis that further studies in the areas of petroleum and transportation are needed to evaluate transportation, not only of food but of the other items essential to postattack recovery.

9.4.2 Calculations for meat supply analysis

The following is backup data for the preceding analysis:

New York State - Meat Supply

1. Population 16,782,000
2. Cold storage volume 94,064,000 cu. ft.
3. Cold storage weight:

To allow for space occupied by aisles and space to allow refrigerated air to circulate between pieces of hung meat, the ratio of meat to cubage is 5 lbs. of hung meat per cubic foot. This conversion factor was obtained from data furnished by a Packing Company whose cold storage volume is 8,512 cu. ft.[32]

There are 8 racks with 24 hooks on each rack and each hook carries 200 lbs.

$$\therefore \frac{8 \text{ racks} \times 24 \text{ hooks/rack} \times 200\#/\text{hook}}{8512 \text{ ft.}^3} = 4.51\#/\text{cu. ft.}$$

(Use $5\#/\text{ft.}^3$)

Storage Weight = 94,064,000 x 5 = 470,320,000 lbs.

$$\text{or } \frac{470,320,000}{2000} = 235,160 \text{ Tons}$$

4. Duration of Supply (One-Time Stocking)

Avg. Yearly Consumption = 161#/person

$$\text{or } \frac{161}{12} = 13.4\#/\text{person/month}$$

Total Consumption of population/month

$$\frac{16,782,000 \times 13.4}{2000} = 112,439.4 \text{ tons/month}$$

$$\frac{(\text{Total Storage})\ 235,160}{(\text{Consumption})\ 112,439} = 2.08 \text{ months}$$

5. Truck Data

Distance N.Y.C. to Chicago	= 850 miles
Roundtrip N.Y.C. to Chicago	= 1700 miles
Maximum Capacity (peacetime) of truck	= 20 tons
(Storage Weight) 235,160 tons / (Truck Capacity) 20 tons	= 11,758 truck loads
11,758 truck loads x 1700 miles	= 19,988,600 truck miles (say 20 million)

Assume 10 miles/gallon as fuel consumption

$$\frac{20,000,000}{10} = 2,000,000 \text{ gallons of diesel fuel}$$

6. Refrigeration Unit

Thermo-King: Uses 1/2 gal. of gas/hour
Runs @ 1 hr. out every 2 hrs.

Maximum running time = 1/2 gal./hr. x 30 gals. = 60 hrs.
50 gals. = 100 hrs.

∴ Uses 1/2 gal. every 2 hrs. or 6 gals. per day. For a 3-day run from Chicago:

211,680 gals. gas = 6 gals./day/truck x 3 days x 11,758 truck loads

7. Livestock production within state

	One Year's Production	
	Live Weight (lbs)	Dressed Wt. (lbs)
Cattle & Calves	385, 330, 000 x . 555* =	211, 931, 500
Sheep & Lambs	8, 063, 000 x . 477* =	3, 846, 000
Hogs	23, 938, 000 x . 569* =	13, 620, 722
(* Conversion factor by Dept. of Agriculture)		229, 398, 222

$\frac{229,398,222}{12}$ = 19, 100, 000#/month

or 9550 tons/month

For 2 months, production = 19, 100 tons

2 month's production $= \frac{19,100}{235,160}$ = .081 or 8% of total storage

1 month's production $= \frac{9550}{112,439}$ = .085 or 8.5% of total monthly consumption

Northeast Area - Meat Supply

1. Population

New England	10, 509, 367
New York	16, 782, 304
Pennsylvania	11, 319, 366
New Jersey	6, 066, 782
Delaware	446, 292
Maryland	3, 100, 689
D. C.	763, 956
	48, 988, 756

2. Cold Storage Volume

New England	47, 166, 000 cu. ft.
New York	94, 064, 000
Pennsylvania	40, 951, 000
New Jersey	37, 639, 000
Delaware	1, 929, 000
Maryland & D. C.	11, 199, 000
	232, 948, 000 cu. ft.

3. Cold Storage Weight

$232,948,000 \times 5\#/\text{ft.}^3 = 1,164,740,000$ lbs.

or 582,370 tons

4. Duration of Supply (One-Time Stocking)

$$\text{Consumption} = \frac{48,188,756 \times 13.4}{2000} = 328,000 \text{ tons/month}$$

$$\frac{582,370}{328,000} = 1.8 \text{ months}$$

5. Truck Data

$$\frac{\text{(Storage Weight)} = 582,370 \text{ tons}}{\text{(Truck Capacity)} = 20 \text{ tons}} = \underline{29,119 \text{ truck loads}}$$

29,119 truck loads x 1700 miles = 49,500,000 truck miles

$$\frac{49,500,000}{10} = \underline{4,950,000 \text{ gals. - diesel oil}}$$

6. Refrigeration Unit

6 gals./day/truck x 3 days = 18 gals./truck

29,119 x 18 = 524,000 gals. - gasoline

7. Livestock Production within Northeast Area -

	Cattle & Calves	Sheep & Lambs	Hogs
New England, N. Y. N. J., Pa.	1,042,990,000	23,444,000	266,275,000
Delaware, Md.	142,035,000	2,655,000	61,793,000
Live Weight =	1,185,025,000	26,099,000	328,068,000
	x.555	x.577	x.569
Dressed Weight =	658,000,000	12,400,000	187,000,000
	12,400,000		
	187,000,000		

Total Dressed Weight = 857,400,000 lbs./yr.
Production/yr.

$$\text{or } \frac{857,400,000}{12 \times 2000} = 35,700 \text{ tons/month}$$

$$\frac{35,700 \text{ tons/month}}{328,000 \text{ tons/month}} = 10.9\%$$

10. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

CONTENTS

10. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

10.1 General

From a structural point of view, the various manufacturing facilities within the food industry exhibit far more variety than do comparable components of many other industries, with the logical result that vulnerability and repair problems are similarly heterogeneous. For example, there is a far greater range in vulnerability between the sardine plant, which can fail at 1.2 psi, and the edible oil plant which is still repairable at overpressures up to 12 psi, than was found between various power plants and between two steel mills evaluated in earlier studies of the electrical and steel industries.[26, 33] But while individual plants may be highly vulnerable, the overall vulnerability of the food industry is low due to the presence within the continental United States of large quantities of stored surpluses, the relatively high degree of redundancy in terms of the possibility of substituting one kind of food for another, and the high degree of overcapacity on the basis not only of our ability to produce food surpluses, but of the four-to-one ratio between the current American diet and a minimum subsistence diet. The per capita annual food consumption in the United States of 1455 pounds[23] could be compared with the 1 pound per day or 365 pounds per capita per year required for subsistence, as described in the appendix.

Certain categories of food production could be completely destroyed by a specific attack; among these are yeast and possibly citrus fruit. Any of these could be replaced, in terms of nutritional requirements.

The problem remaining is the final stage, namely the transportation of food to the consumer and its equitable distribution. Distribution will depend largely on the availability of petroleum, which is currently being studied.

Food importation, as a short-term survival measure, has limits to its practicality. Current domestic food supplies, in edible form, could feed the population for at least 110 days. If unprocessed commodities are added to this, the food supply is measured in years (section 2.1.1). The first problem will be transporation to distribute the food, and the second will be the restoration of food processing facilities.

10.2 Vulnerability and failure patterns

In general, vulnerability varies from one plant to another. An example of this variation in vulnerability is in the food container portion of the study: although the two plants studied both produce cans, a wide variation in vulnerability is evident.

Failure patterns are generally similar, however, beginning with structural damage to the building, followed by collapse of the building on the production machinery, thereby destroying the machinery at a lower level of blast overpressure than that to which the machinery would otherwise be vulnerable.

Of all the damaging effects of nuclear weapons, fallout presents the least problem. In some industries, the rapid shutdown associated with panic of a nuclear attack could cause damage comparable to that from the other, more direct effects such as blast. An example of this is to be found in the steel industry.[34] No such problems were found in the food industry sample studied.

Little direct vulnerability to thermal radiation was found. Only in the sardine plant is there a fire problem; the fire, if any, in this plant would probably be the result of secondary fires arising from conditions caused by the shock wave.

The primary cause of damage would be nuclear blast. Levels of blast damage to cause certain repair requirements vary quite drastically from plant to plant, although some inverse correlation is evident, in that the plants less vulnerable to blast due to their stronger construction require more repair effort.

No fallout shelters were found at the various plants studied, although certain areas in some of the plants are suitable for use as shelters. Under certain attack conditions, one assumption of this study might not be valid, namely that a sufficient number of skilled repair personnel would be available. Little problem is evident in the area of either bacteriological or radiological contamination. Normal processing techniques tend to remove much, if not all of any fallout present, and normal precautions to comply with preattack sanitary requirements would be quite adequate in the postattack environment.

A high level of postattack repair capability was found at every plant studied. If an "islands of survival" situation were to result, sufficient personnel would be available locally to handle the repair problems. However the wide distribution of the raw materials for processing might preclude their availability to the processing plant in a postattack situation, and accordingly the production of the plant would be curtailed.

10.3 Fallout

Plant shutdown is not a serious problem in any of the cases studied; startup following even a prolonged shutdown would involve only minor delays, at worst. Fallout shelters for plant personnel are not available in any of the plants studied, although in most cases there is sufficient existing space with a high-enough protection factor. In some of the food industries, food for emergency purposes could be a very simple problem, due to the in-plant presence of an appreciable stock of processed food. Since the postattack recovery of the food industry depends upon the presence of trained personnel, perhaps some special incentives should be offered to the industry to provide the shelters needed to protect these personnel.

10.4 Transportation and distribution problems

Every component of the food industry depends on transportation. Agriculture requires transportation both for supplies, and to deliver the product to the manufacturer. Similarly, the manufacturer, the wholesaler, the retailer, and even the shopper in our automobile-oriented society, depend on transportation for the delivery of supplies and products. The Meat Industry Study, chapter 9, provides a sampling of the magnitude of the problem in one particular area. As indicated in that study, the most vulnerable component of transportation is pet[illegible]um.

Further work should be done to resolve uncertainties associated with the transportation problem. A current study now in progress is directed at the vulnerability of oil refineries; following that study, a survey of the food transportation problem is in order.

10.5 Shortcuts

One particular characteristic of this industry is its superfluity, the wide range of substitutions available, and the number of processes which could be omitted in a postattack emergency situation.

The food industry, more so than most others, is characterized by a high degree of interchangeability and adaptibility in its various products. The manufacturing of frozen orange juice concentrate for example, although unquestionably efficient and economical in terms of our present economy, could be dispensed with entirely in a postattack survival situation; whole, unprocessed fruit as it comes from the tree could be substituted, as could other sources of vitamin C, which is cheaply and easily synthesized. Similarily, unprocessed wheat grain is reasonably palatable and nourishing, although rather hard to chew and to digest unless boiled. A similar pattern of shortcuts and possible substitutions exists throughout the industry, limited only by the basic nutrition requirements itemized in the appendix.

10.6 Spare parts and cannibalization

Due to the diversity of the various components of the food industry, little cannibalization of parts from one type of product to another is possible. In fact, different plants in the food industry have less in common with each other than do other plants in most other types of industries. Key equipment such as an orange juice evaporator, a hydrogenation unit for vegetable oils, a flour sifter, or a sardine retort, have essentially nothing in common. A possible exception exists in the case of can sealers, where it would be possible to interchange equipment, if a sufficiently clever machinist were doing the interchanging. Care should be used to prevent misapplication of this approach, since many difficulties might be encountered. Cans for frozen orange juice, for example, do not have to be hermetically sealed, since the product is stored frozen, and is sufficiently acid in nature to discourage bacterial growth at low temperatures. Various "hot packs", such as tuna, require extreme care to avoid any contamination. Hence these cans may not be interchangeable. More details on the canning industry are available in chapter 6.

Other cannibalization is discussed under the individual industries, together with the desirability of spare parts.

10.7 Range of applicability of results of the study

The difficulty of selection of a "typical" plant includes not only the variations in analysis of production machinery, but also the variation in the structures which offer weak links in the overall analysis of potential damage. Some insight into the degree of variation can be given by the analysis in chapter 6 involving two different plants, both of which produce metal containers for food packaging. One of these plants is a relatively modern one-story structure, the other a much older multi-story reinforced concrete unit. The two plants are quite different in the vulnerability to blast damage, differing by a factor of almost two to one.

A two-to-one variation of the vulnerability of the plants could be expressed as a plus or minus 33% variation about the mean, and this might provide a reasonably good estimate of the accuracy due to this factor of differing construction.

The accuracy of the damage calculations depends on assumptions used in the damage analyses. For example, the values of the ultimate strengths and ductility factors of construction materials differ according to the source selected. Settlement cracks or flaws in unreinforced masonry would contribute to the inaccuracy of the results. The estimated accuracy of $\pm 25\%$ would apply here.

Estimates of men, materials and equipment for new construction will vary little between estimators because construction techniques for a particular job are fairly standard. However, repair estimates will vary widely since variations exist in the manner in which repair can be made. The repair of a critical industry will require the fastest repair method but not necessarily the most economical. For example, one estimator may decide to straighten a steel member by heat and a jacking process; another estimator may decide to shore the facility, remove the damaged member and replace it with cannibalized or new material.

Other factors which influence the repair estimate are the availability of men with the disciplines required, and the availability of materials and equipment. A crane without an operator, (lack of the services of an oiler), or an operator without a crane will influence the manner in which steel is erected or high concrete lifts are made. As for materials, plastic sheets may be used instead of glazing or corrugated plastic siding applied to the framework with an epoxy glue may be used instead of corrugated metal or abestos siding applied with mechanical fasteners -- a considerable saving in time _if_ plastic products are available in the area.

Postattack economics will certainly play a role in repair or rebuilding. Repair in the high damage range can cost considerably more than new construction in peacetime. However, the exigencies of the postattack environment may dictate repair rather than rebuilding anew.

An adequate sample to permit extrapolation of these results to the entire industry would require many times the number of plants, distributed over the industries studied in this report and other portions of the food industry.

10.8 Repair and hardening

All the plants have good repair facilities which could greatly aid postattack repair efforts provided, of course, that the maintenance shops themselves were not destroyed by the blast; and that repair personnel were available. The assignment of priorities is essential to any repair plan, beginning perhaps with the maintenance shop itself, then repairing those damaged facilities and equipment which will be capable of at least restoring limited production in the shortest possible time. Most of the food plants are somewhat less automated and less integrated than are plants in industries such as petroleum, steel, or electric power, and thus repair problems are correspondingly simpler.

Hardening possibilities applicable to industrial plants have been studied in a companion project.[34] Results of this study indicate that expenditures of modest sums of money, relative to the cost of the plant, applied to strengthening of the weakest elements of the plants, can improve the prospects of that particular plant's survival and reduce the damage. The consequent reduction in repair times has not yet been evaluated. Further, the relative value of postattack man-months of labor and preattack dollars should be investigated, with specific conclusions as to how these factors could affect food production.

10.9 Recommendations for future study

A study of the role of emergency postattack food transportation and distribution would be an important and logical sequel to this Food Industry Repair Analysis and to the Petroleum Industry Repair Analysis now in progress. Particularly, further research should be conducted concerning the problem of emergency feeding of the population of the Boston-to-Washington megalopolis under such extreme conditions as would exist if the people survived but the food distribution pipelines were disrupted. One possible solution to this potentially very serious problem might result from further research into the availability of mobile frozen storage space. Refrigerated trucks could be used for emergency storage as well as transportation of large quantities of frozen food. Statistics on refrigerated shipping indicate that vessels under United States control could store enough meat to supply the needs of approximately 16 million people for 3 months, which could help to solve the problems of feeding people in cities located near the seacoasts or Great Lakes. This and other possible solutions should be examined, and practical techniques for implementation of these solutions recommended.

The repair data from selected plants within the industry have not been projected to the entire industry. In the current petroleum study, methods of accomplishing this are being investigated. For a rigorous statistical approach it is desirable that a random sample of plants be analyzed, and the data obtained be projected to all plants in the industry by the conventional techniques of standard deviation estimating and curve fitting of the data against significant parameters. In this way, the repair of the entire industry can be estimated within a given level of confidence. In the industries studied by us, however, plants to be analyzed were not selected randomly, but instead were selected on the basis of some particular physical characteristics or experiences they had undergone. It would be worthwhile to make a study of the national postattack repair of one component of the food industry, using rigorous statistical methods, and analyzing a statistically significant number of plants.

APPENDIX A

APPENDIX

DISCUSSION OF BASIC NUTRITIONAL REQUIREMENTS *

A.1 Introduction

In the most literal sense, the living organism is the food it eats. The function of food is twofold. First, food supplies the nutrients which, after profound and elegant transformations, results in the living body. Second, food often is part of the human emotional environment, providing comfort and security. It is upon these aspects of the postattack problem that an analysis must be made.

A.2 Immediate postattack period

The survival period has been defined as the first month or so following an attack. In general, during these short periods, the supplying of nutrients should not be a major problem since many of the major nutrients are stored in the body to a considerable extent. In this category are the essential minerals, all the fat soluble vitamins, vitamin C, and all the B vitamins with the possible exception of thiamine. Moreover, the needs for other nutrients such as protein and energy can be considered to be drastically reduced when relatively short periods are considered. Ultimately, the only nutrient required at any level near-normal is water. Therefore, any consideration of postattack diets must start with the supplying of water and then, in order of decreasing priority, energy, protein, and possibly thiamine. For all the other nutrients, deficiency periods of one month or less should not produce noteworthy symptoms in healthy normal adults. In fact, during the earliest periods, only water would have to be supplied.

In quantitative terms, the following daily allowances should prove suitable for maintenance of normal healthy individuals over four years of age, but excluding pregnant and lactating women:

water	1 quart or more
energy	1200-1500 Cal.
Protein	35 gm.
thiamine	1 mg.

Note, for example, with the exception of the water allowance, one pound of enriched bread will supply all of these required nutrients. Therefore, substitutes to ordinary diet are readily available.

* Prepared by Dr. Sanford A. Miller and Dr. Nevin Scrimshaw, Department of Nutritional Sciences, Massachusetts Institute of Technology, in cooperation with Advance Research, Inc.

For special groups, these daily allowances should be increased as follows:

	Energy	Protein	Thiamine
infants to 6 months	110 Cal/kg	3.2 gm/kg	0.4 mg
pregnant women	2400 Cal	80 gm	1.2 mg
lactating women	3000 Cal	95 gm	1.6 mg
children 6 mo. to 4 years	1200 Cal	35 gm	0.6 mg

It is possible to improve the basic bread diet to meet these needs by adding a dried fat free milk allowance. Similar allowances can be derived for the injured and sick. These, however, would be dependent upon the extent and type of injury or illness.

It is apparent, therefore, that the function of food to supply nutrients should not prove to be a major problem during this immediate postattack period. Under prolonged postattack conditions, monotony of diet may prove to be a problem. Consideration must be given, therefore, to the possibility of providing more varied diets than the bread and water diets discussed earlier, particularly if the postattack period is extended.

A.3 Extended postattack period

Under conditions of an extended postattack period, i.e., periods longer than one month, it is possible that additional nutrients may become limiting. Some of these are listed in table A-1 and are discussed below.

Calcium is required for a number of physiological purposes, including the proper growth and development of bone and nervous tissue. The amount suggested for adults should be sufficient to cover all requirements. For the pregnant and lactating woman, this should be raised to 1.5 gm/day to meet the increasing demands of the fetus and for milk production. For the very young child, 1-9 years, the allowance can be reduced to 0.8 gm/day. This, however, should be raised to 1.5 gm/day during the rapidly growing period 9-18 years of age. With the exception of the pregnant and lactating woman and the infant, no problem with this nutrient should be encountered for periods of less than six months.

Phosphorus, needed for growth and bone development, should not prove to be a problem at any time. It is widely distributed and, if calcium and protein needs are met, sufficient phosphorus should be available. In general, other nutrients should become limiting long before phosphorus becomes a problem.

Iron is required for the proper synthesis of the hemoglobin portion of the blood. Extended deficiency can result in anemia. The body, however, has a remarkable capacity to store and reuse iron. In adult men, overt deficiency would probably require more than a year to become developed. Due to their periodic iron losses during menstrual bleeding, the requirement for women is somewhat higher than that for men. Adolescents also have a somewhat higher requirement. The amounts listed in the table should be adequate to meet most needs.

Table A-1 SELECTED NUTRIENT REQUIREMENTS

Nutrient	Minimal Requirements		Time For Deficiency		Comments
	Young	Adult	Young	Adult	
Calcium	1.5 gm/day	0.8 gm/day	6 mo.	not determined	Should be considered for long term problem
Phosphorus	2.0 gm/day	1.0 gm/day	not determined	not determined	Difficult to produce deficiency since it is widely distributed
Iron	10 mg/day	15 mg/day	more than one year		Continued deficiency causes anemia
Iodine	100-120 micrograms/day		more than one year		Defic. causes goiter. Can be supplied by iodized salt
Vitamin A	2000-2500 I. U./day		3-6 mo.	over 6 mo.	Much is stored in body, probably one year's needs.
Vitamin D	200-250 I. U./day		6 mo.	more than 6 mo.	Causes rickets in young and osteomalacia in adults
Vitamin K	Very difficult to produce deficiency				Antibiotic therapy may increase need
Riboflavin (B_2)	1.0-1.5 mg/day		less than one year	more than one year	No problem if milk available
Niacin	15 mg/day		less than 3 mo.	less than 6 mo.	Particularly profound when corn is staple
Pyridoxine (B_6)	1-2 mg/day		less than 2 mo.	less than 3 mo.	Widely distributed defic. unlikely if other needs met
Vitamin B_{12}	very low		more than 6 mo.	1-3 years	Best sources are meat or milk. Deficiency causes anemia
Vitamin C	10-20 mg/day	30-40 mg/day	approx. 4 mo.	more than 5 mo.	

Iodine is required for proper functioning of the thyroid. Deficiency in the adult results, generally, in goiter. As with iron, however, the body efficiently stores and reutilizes its iodine. Thus, deficiency periods of one year or more are generally required for symptoms to appear. The use of iodized salt in cooking and baking would provide all the iodine required.

Vitamin A and D. These "fat-soluble" vitamins are considered together since they are found in the same foods. Both are stored extensively and should not prove to be problems for periods of 4 months or less. Deficiency of vitamin A results in night blindness and other ocular problems while vitamin D is required for growth and maintenance of the skeleton. The use of fortified milk would obviate any danger from deficiencies of these vitamins.

Vitamin K requirements are difficult to assess since it is widely distributed and is also synthesized by the intestinal microflora. It is required for blood clotting and is included in this table since anticoagulant and antibiotic therapy may increase dietary needs. Under normal conditions, however, this vitamin should present no significant problem.

Riboflavin (vitamin B_2) deficiency should not prove to be a problem for periods of six months or less. Beyond this point, a variety of metabolic disfunctions may appear since this vitamin is required for many key metabolic steps. If milk is included in the diet, no problem should exist since milk is an excellent source of this vitamin.

Niacin is another vitamin required for essential metabolic steps. Deficiency of this vitamin can result in pellagra. Since the amino acid, tryptophane, found in protein, can be converted to niacin, it is difficult to assign a dietary requirement for the preformed vitamin. In general, it is considered that 60 mg of tryptophane or niacin is included in the diet, deficiency will result in 6 months or less. The presence of extensive amounts of corn in the diet can aggravate this condition since there is present in corn a factor which will prevent niacin utilization.

Pyridoxine (vitamin B_6) is required for protein synthesis and its dietary level is intimately associated with the dietary level of protein. Since the body does not store extensive amounts of this vitamin, deficiency periods of 3 months or more in the adult and 2 months in the rapidly growing young can result in an overt syndrome. Since this vitamin is widely distributed, meeting the requirement should not prove to be a problem if other needs are met.

Vitamin B_{12} should not, under normal conditions, prove to be a problem. Its requirement is low, and is widely distributed as well as being efficiently reutilized. It may become limiting under conditions where the intestinal environment is modified as in antibiotic therapy. Since it is required for the synthesis of the red blood cell, deficiency may result in anemia.

Vitamin C deficiency symptoms (scurvy) may appear after periods of 4 months. Since this vitamin is very labile, some care must be taken in supplying it if periods of longer than 4 months are contemplated.

In addition to the nutrients listed in table A-1, a large number of other nutrients may be considered. These, however, are so widely distributed or are required in such small amounts and are utilized so efficiently that they should not be significant except under very abnormal conditions.

The concept of "islands of survival" should present no significant nutritional problems. Each area of the country can provide some source of protein and calories. If periods are limited to one or two years, the quality of the protein in these sources should not be a significant problem. Furthermore, the use of multivitamin and mineral supplements which can be stockpiled quite easily should solve any other problems of trace nutrient deficiency.

A.4 Protein concentrate

It has been suggested that a widely available and easily stored protein source be stockpiled. Among those foods suggested has been fish meal or fish flour. This high protein source is prepared from whole "so called" trash fish, that is ground and extracted to remove fat and odiferous material. Much work has been done to demonstrate that this material, when properly prepared, is of high quality and can be of significant value.[35, 36] Similar products have been used with success in food supplementation programs in Africa and South America.[37, 38, 39] The major problems appear to be concerned with flavor, the use of toxic species of fish and inadequate solvent removal. If proper quality control procedures are established and maintained, a high quality, low cost product of high nutritional potential can result. At the present time, an extensive research program in the area is in progress at the Fisheries Technology Laboratories, USDI, College Park, Md. This work, under the direction of Dr. Donald Snyder and Mr. Ray Pariser is attempting to solve some of the problems associated with commercial production of fish flour.

It should be mentioned, at this point, that the use of fish flour in human food in the United States has not been allowed by the Food and Drug Administration. Their argument that a fish flour prepared from whole fish would be adulterated and contaminated with material defined as "filth" is currently under debate. The question is one of aesthetics and should be resolved in a reasonable length of time.

A.5 Monotony and acceptability of diets

If the concept of "islands of survival" is followed, consideration must be given to the problem of monotony and acceptability of diets. Unpublished work at M.I.T. with students fed a formula diet for extended periods of time indicate that a significant number of subjects become intensely disinterested in food. This appears to be a cyclical problem, appearing and leaving at fairly uniform intervals. Although these interludes do not appear debilitating it is possible that continuation for longer periods may produce difficulties.

The problem of low acceptability is also difficult to document. It is well known among animal researchers that animals fed diets which are not of high acceptability tend to reduce their intake to a point where a variety of nutritional problems arise. S. Lepkovsky at the University of California at Berkley has reported a number of unpublished observations on soldiers during World War II. In these studies, soldiers fed rations which were not particularly acceptable tended to maintain very low food intakes, occasionally resulting in minor nutritional problems.

Whether the twin problems of monotony and acceptability are significant in the context of the postattack situation in unknown. In any case, they should be considered.

A. 6 Summary and conclusion

In summary, therefore, it would appear that, for a postattack period of two to four weeks, nutrition should not be a major problem. If normal levels of energy, protein, and possibly thiamine are supplied, as in the form of enriched bread, people should be able to survive and work efficiently. Only water must be supplied at near normal levels. Consideration must also be given to the needs of special groups. These requirements, however, may be supplied by milk supplements to a bread diet.

For extended periods, consideration must be given to other nutritional factors. Many of these can be supplied by multivitamin and mineral preparations, some by the use of more varied diets.

The "island of survival" concept also raises a number of problems including monotony and acceptability. The effect of these on human efficiency and performance is unknown but worthy of consideration. Again, the use of diets of some variability may alleviate the problem.

The use of high quality food supplements such as fish flour also has to be considered. In spite of their known advantage, excellent quality control procedures would have to be elaborated and maintained before such products can make a significant contribution.

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GLOSSARY

angle of repose: the greatest angle at which the slope of a granular material will remain in equilibrium.

bent: a steel or concrete frame composed of a beam supported by two or more columns.

boiler feed: water supplied to a boiler for the production of steam.

brix: a term used to define the percent solids in a solution by weight. For example, 42° brix indicates 42% solids.

bunker C: a low grade of fuel oil.

cannibalize: to repair a piece of equipment or machine by using a part from another machine.

char filter: a vessel containing bone char through which melted raw sugar is passed to filter impurities and color.

chills: heavy steel rollers used in the flour industry which rotate against each other to break up the wheat berry.

chilled juice: fresh, single-strength fruit juice usually packed in paper cartons and kept under refrigeration.

clarifiers: equipment which remove foreign material from the sugar.

deodorizing: the steam distillation of an edible oil under partial vacuum to remove lighter components.

fenestration: the state of having windows in a wall of a building. The amount or percentage of window area.

fixed end: a condition of rigid fixity at the connection of a column and its foundation thereby transmitting all stresses from column to foundation.

interesterification: a catalytic chemical process which rearranges atoms within and between fatty acid radicals to convert one edible oil to another.

girt: a steel member, generally a channel, which is connected horizontally to the steel columns of a mill building and runs continuously from one end of the building to the other and which supports the siding material.

glassine: a thin dense paper highly resistant to the passage of air and grease.

hammer mill: a device which pulverizes sugar crystals into a powder.

hotpack: used to describe a juice which has been pasteurized by heat when it was packed.

hydrogenation: a chemical process using a nickel catalyst to add extra hydrogen to fatty acid radicals to increase the saturation of an edible oil.

insulbric: a trade name for an asphaltic covering applied to the exterior walls of a wooden structure to give the appearance of brick wall.

man-day: one man working eight hours.

marine leg: a conveyor which is inserted into the hold of a ship to unload its cargo. An integral part of a marine tower.

marine tower: a large multi-legged tower which travels on steel rails on a pier and is used to unload boats.

melt liquor: the liquid residue after water, molasses and impurities have been removed by centrifuge from the mixture of sugar and syrup.

mingler: a screw or auger conveyor used in a sugar refinery.

overpressure: pressure above normal atmospheric pressure and measured in pounds per square inch (psi).

party wall: an exterior wall which is common to two buildings.

pin end: a condition of non-fixity at the connection of a column and its foundation. One which transmits only horizontal and vertical forces from column to foundation.

press filter: a tank containing bone char through which sugar syrup is forced in order to remove color and produce a water-white liquor.

purlin: a steel or timber member affixed to the main roof beams or trusses and runs the full length of the building and to which the roofing material is connected.

rigid frame: a steel or concrete frame or bent composed of a beam and columns which are rigidly connected.

shear diagonal: a brace installed diagonally between a column and a beam.

shear wall: a wall built integrally with slabs and columns and designed to resist large lateral forces such as wind, earthquake and blast.

siding: a term given to materials used as exterior walls on buildings, e.g. corrugated metal sheets commonly seen on mill buildings.

single strength: non-concentrated fruit juice, either canned, fresh, or "chilled", which does not require the addition of water by the consumer.

tradesman: a person engaged in a trade such as a steel erector, welder, mason, carpenter, glazier, etc.

unscrambler: a machine which aligns cans that arrive at the plant in a scrambled condition.

zulauf machine: equipment which supplies the correct amounts of yeast starter and molasses for the maximum production of yeast growth in a minimum amount of time.

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13. ABSTRACT

The American food industry is analyzed in terms of vulnerability and postattack repair. Processing plants in eight specific segments of the industry are selected on the basis of essentiality and vulnerability: flour, yeast, sugar, citrus fruit, edible oils, fish, meat, and packaging (cans and cartons).

Vulnerabilities of the plants vary by a whole order of magnitude. The most vulnerable plant faces total destruction at a relatively low 1.2 psi blast overpressure, and the least vulnerable plant is still repairable after a blast of up to 12.0 psi. The older, more massively built plants are generally least vulnerable, hence present the fewest repair problems at any given blast level.

There are two general conclusions. First, a severe shortage of both raw and processed food stuffs is improbable, because food manufacturers are both numerous and geographically dispersed. Second, food in one form or another, including ample reserves in the form of stored, surplus commodities, will be available but must be transported. An adequate supply of petroleum is essential to insure the transportation which will provide the food supply.

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