

DESIGN OF  
REFRIGERATION SYSTEM  
FOR  
KNOXVILLE MUNICIPAL MARKET HOUSE  
AND  
PRELIMINARY SURVEY  
ON  
COMPARISON OF  
INDIVIDUAL AND CENTRAL REFRIGERATION PLANTS  
FOR APARTMENTS

A THESIS  
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ROBERT MOORE CONDRA  
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## INTRODUCTION.

Mechanical refrigeration made its first appearance in practical application about 1850. Since then it has invaded, either directly or indirectly, most every field of the modern production and manufacturing system. It is today found in hotels, restaurants, club houses, creameries, packing houses, refining companies, and many manufacturing concerns, besides being used in numerous other places for widely varied purposes. From the crude inefficient methods used seventy years ago, the practice has grown and developed into the present system of ice manufacturing plants, storage houses, and other applications as mentioned above.

At one time in 1918 there was a total of one billion, five hundred million pounds of meat in cold storage. This same approximate amount of eggs, butter, fish, lard, and fruit were being stored at the same time. Thus, this problem is one of growing importance, and deserves much study; in fact, more than to date, has been given to it.

The existence of the public depends today upon the possibilities of storing produce from one season to another, and also of shipping perishable goods from one place to another without impairing the quality of the same. By means of the cold storage houses and refrigeration cars, the two above mentioned factors are taken care of. Consequently, in most every city can be seen the representative products of all climates. Not only is the variety of foodstuffs increased by these means, but the supply and consequent price of many products is leveled to within the reach of all.

From the above conclusions it is apparent that the field of mechanical refrigeration is a large one. Regardless of the present magnitude, though, of the various methods and their applications, there is room for much improvement in each, and expansion in old as well as new fields. Some of these new fields are beginning to appear on the horizon today and may or may not prove themselves to be a success, according to whether or not they will perform an economic service to the public.

Among these new fields is the possibility of equipping market houses, and other buildings housing a number of ice consumers, with mechanical refrigeration. This may be accomplished either by means of a central located plant or by individual plants for each box. The central plant system would, without doubt, be the more economical for the market house project, but its application to apartments and other similar places is contested by the recent introduction of the individual automatic plants. A comparison between these systems is made in a later part of this work.

At present, ice is manufactured at a central plant; loaded into wagons or trucks, carried around the city, and finally delivered to the consumers, one here and one there. In many places the amount of ice delivered to a single building runs up into the thousands of pounds per day. The most outstanding example of this practice is found in the market house of today. With the many individual ice boxes, refrigerators, and so forth which have to be recharged each day, this situation presents a problem for the efficiency engineer. A similar example on a smaller scale is the apartment house containing usually a collection of families, each with their private refrigerator and ordering ice as they individually need it from their own ice man. Each day, many wagons of different ice companies, stop and deliver ice to their respective customers, some of which are on the first floor and some on the top. Thus it is that at least one ice wagon can usually be found in the near vicinity of a large apartment at any time during the day.

Does this not look like a very inefficient system? Water is taken at the plant, treated, then made into ice, placed on the wagons, and after a few hours of exposure to the sun and air, delivered to the place where it can finally accomplish useful work. Labor and power are required to make the ice, take it from the brine, load into storage rooms, then into the wagons and finally from the wagons into the individual storage boxes or refrigerators.

Consequently the cost of this product to the consumer is no small item, the retail prices usually ranging from fifty to sixty cents per one hundred pounds. The cost to the manufacturer has been determined by tests made on various ice plants situated in all parts of the United States. The results of a forty-eight hour test, on the Diamond Ice Company of this city, are recorded in a later chapter. The entire plant had just recently been overhauled and remarkable low figures on actual cost were obtained. Note should be made of the ratio of the actual cost of manufacturing to the delivered cost. According to Azbe, in his report on ice production, A. S. M. E. for 1918, the average number of tons of ice per ton of coal is about 6.7 for compound condensing plants, and 3.3 for simple non-condensing plants. (See table ). By comparison with test results, the good condition of the local plant is clearly demonstrated, and it might be stated here that few plants ever run over this figure. On the other hand many ice plants do not even show the indicated average results as given by Azbe in his report, but go year in and year out with a production of only 1 1/2 and 2 tons of ice per ton of coal. This poor efficiency is an economic loss to society, and steps should be taken to reduce the loss to as low a figure as possible.

In addition to the actual cost of this power and labor required in moving the ice from the manufacturer to consumer, there is the factor of continual abuse to furniture and fix-

tures of the consumer by the delivery element. Necessary daily contact with a troublesome and many times undependable ice man, is a thing of the past. Wet foot-prints on clean floors, spilled and ruined food, hours spent in waiting for ice man, and other such common occurrences of today, are forgotten when using one of the systems of modern refrigeration. The ice delivery system, besides being a source of continual trouble and expense to each apartment occupant in even more ways than stated above, is a very inefficient system and research should be carried on and experiments made until the excessive losses of today are reduced to a much lower figure.

The question arises: "Is it possible to increase this efficiency?" There is no doubt about the present percent being very low, especially if the factor of satisfaction and service to the public, is concerned. The present individual automatic refrigerator is one example of many attempts to raise this figure; the central refrigeration plant installation in apartments as well as market houses, is another. Both systems have proven to be more or less of a success even if the fact is considered that each idea is still in its infancy, and study has comparatively just begun.

In the following pages the advantages and disadvantages of these advance systems will be brought out as much as possible, with the ultimate object of determining: first, the economy of central refrigeration plants in apartments and market houses; second, the economy of installing individual automatic refrigeration units in the latter mentioned case; and third, the advisability of recommending the installation of a central plant in the market house of this city.

#### POSSIBLE REFRIGERANTS AND THEIR PROPERTIES.

The various possible methods of producing refrigeration must first be considered. These various methods, regardless of the amount of machinery and other equipment making up the system, must make use of some substance as a refrigerant. Any substance capable of evaporating and taking up heat at one temperature and pressure, and then giving it up at another temperature and pressure, can be classed as a refrigerant. Due to the many factors influencing the design of machinery, installation of the same, public safety, economy of operation, and so forth, there are but a few substances standing out as practical commercial refrigerants in the present day field of mechanical refrigeration. A few of these substances are listed in this chapter with their respective properties.

By referring to figure , the respective values of the listed refrigerants can be compared. The first four are of such low vapor tension that their entire cycle would be below atmospheric pressure. On account of the unfavorable operating conditions and the required low temperature

to the cooling water, these refrigerants are never used. The next three in the list might be used where a small quantity of refrigeration is required, but due to the large volume of gas handled per ton of refrigeration, this quantity is very limited and actual operation cannot be carried out at temperatures lower than 33 degrees Fahrenheit.

The next in order is Butane, which has been known as a good refrigerant for a long time but only recently has it been obtainable in the pure state. With temperatures no lower than 33 degrees Fahrenheit, this refrigerant would be very successful since it can be compressed in a 50 pound air compressor, and all pipe fittings would be standard. The system using this substance would be entirely safe if given the same attention as the ammonia system, as the gas is not poisonous even if taken in large quantities. By reference to Fig. "2", the volume displacement is found to be about three times that of ammonia. The cost of this system should be less than the installation of the present ammonia system.

Next is carbon dioxide, which of all the commercially plausible refrigerants, has the smallest volume displacement per ton of refrigeration. This is a colorless, odorless gas, and is not harmful except in large quantities. Being heavier than air, non combustible and not capable of forming explosive mixtures with air, it makes a very ideal refrigerant for apartment houses. Due to the exceptionally high pressure range, low pressure being around 290 pounds and high pressure around 900 pounds, the system requires such a large and heavy compressor with correspondingly heavy piping that its installation today is not very successful. Another factor entering into the arguments against this system is the necessity of a cooler condensing water than is found in many parts of the United States. The indirect methods of brine circulation works in well with this system however, and there are today, many such plants as these giving good service.

Ammonia is at present, the most used refrigerant of all. It is a colorless gas, (at ordinary temperature and pressure), combustible, and highly explosive if mixed with the right amount of air. The gas has a very nauseating odor, and so poisonous that relatively small amounts will cause death. It has moderate pressures for around zero temperature in the cooling coils and 70 or 80 degrees in the condensing coils. The corrosive action it has on brass and copper prevent these metals from being used any place in the system. The volume displacement of the cylinder has to be about five times that of the carbon dioxide cylinder, but the refrigerating effect per pound is over seven times as much as that of carbon dioxide.

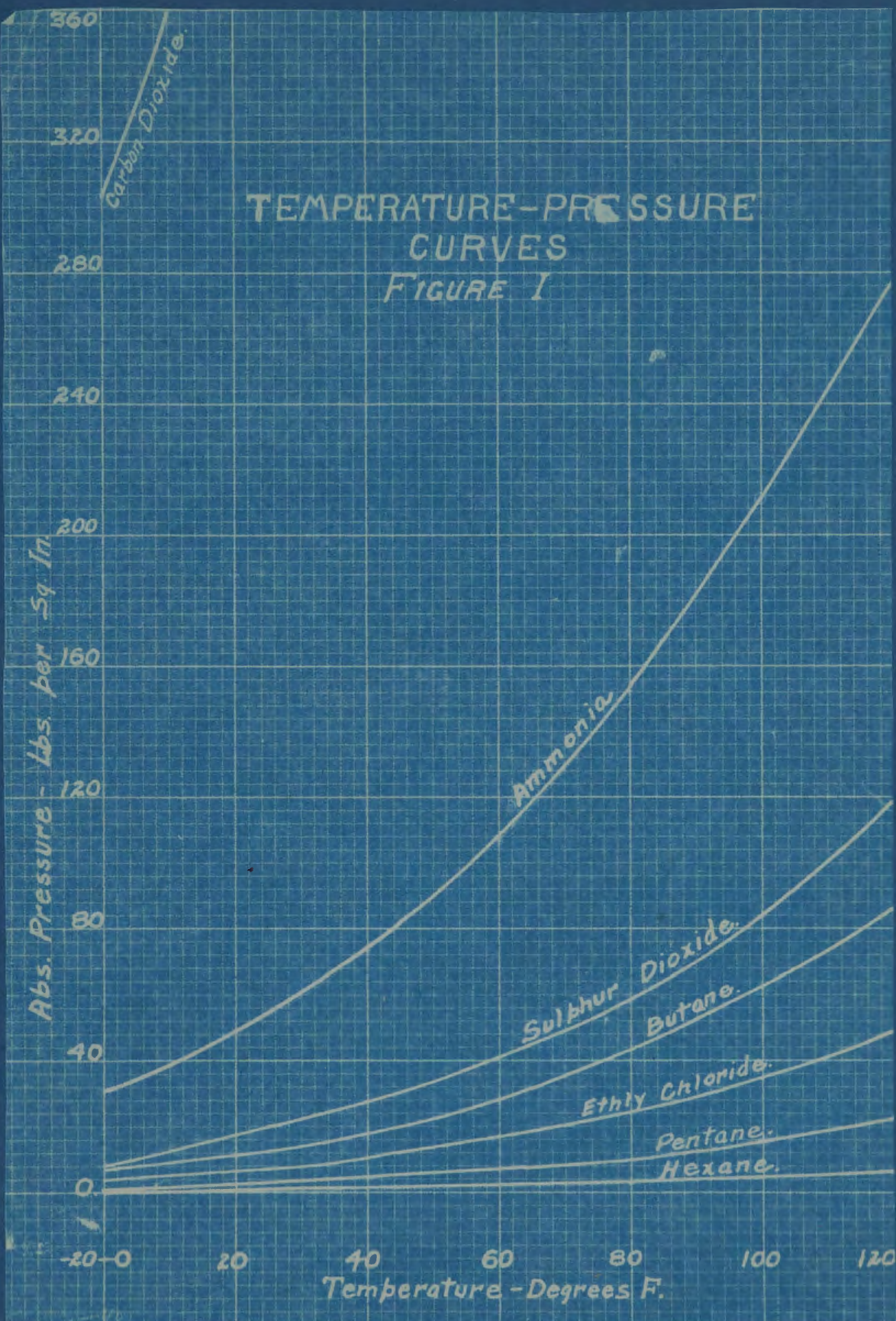
Sulphur dioxide is a colorless gas, very poisonous and fatal if taken into the body in even relatively small amounts. It has a nominal pressure range from freezing to condensing temperatures; this range being much less than that of ammonia, with the low pressure about 20 pounds per square inch lower than the low pressure side of the ammonia system. The corroded-

ing action of sulphur dioxide when mixed with water, on iron and steel is very great. Due to the low pressure being much below atmospheric, thus allowing a possibility of moisture leaking into the system, many engineers do not advocate using this as a refrigerant. However systems are on the market today with sulphur dioxide as the refrigerant, and so far there has been no difficulty with moisture in the system. The volume displacement of the cylinder is about thirteen times that of the carbon dioxide cylinder, while it has a refrigerating capacity of about twice as much per pound.

After referring to Figs. "1" and "2", and knowing the properties of the various refrigerants, the fact can readily be seen that ammonia is the most preferred substance in the refrigeration field of today. The modern engineer is familiar with the pressures met in dealing with this system. The system is a very adaptable one; the high pressure capable of using condensing water ranging from  $50^{\circ}$  to  $90^{\circ}$  Fahrenheit, while the low pressure temperature can be varied from plus  $50^{\circ}$  to minus  $30^{\circ}$  Fahrenheit. The next preferred system seems to be that in which carbon dioxide is used as a refrigerant, but at present, definite facts are lacking on this method. Referring to Fig. "4", the horse power per ton of refrigeration is found to be much more for the carbon dioxide system than for the ammonia installation under the same conditions. Then again, only experts can successfully and economically run the carbon dioxide plant especially if the condensing water is of a very high temperature. The high pressures encountered on the high pressure side of the system are continually causing trouble by leaky connections, and so forth, thereby resulting in a big loss of refrigerant. At present the efficiency of this system is below that of the ammonia plant, but with time and improved compressor designs, it has a very promising outlook.

By a study and comparison of the above mentioned summaries and tables, the ammonia system has been decided upon as the most economical installation for the market house project. The question of direct or indirect expansion, though, is still one of debate. No doubt but that each of the above mentioned systems have their own particular field of excellence, and the question to be solved is which field the market house installation will come under. The above conclusions also apply to apartment house installations using the central plant system. In the apartment installations, however, the central plant has the individual refrigerating machines to compete with.

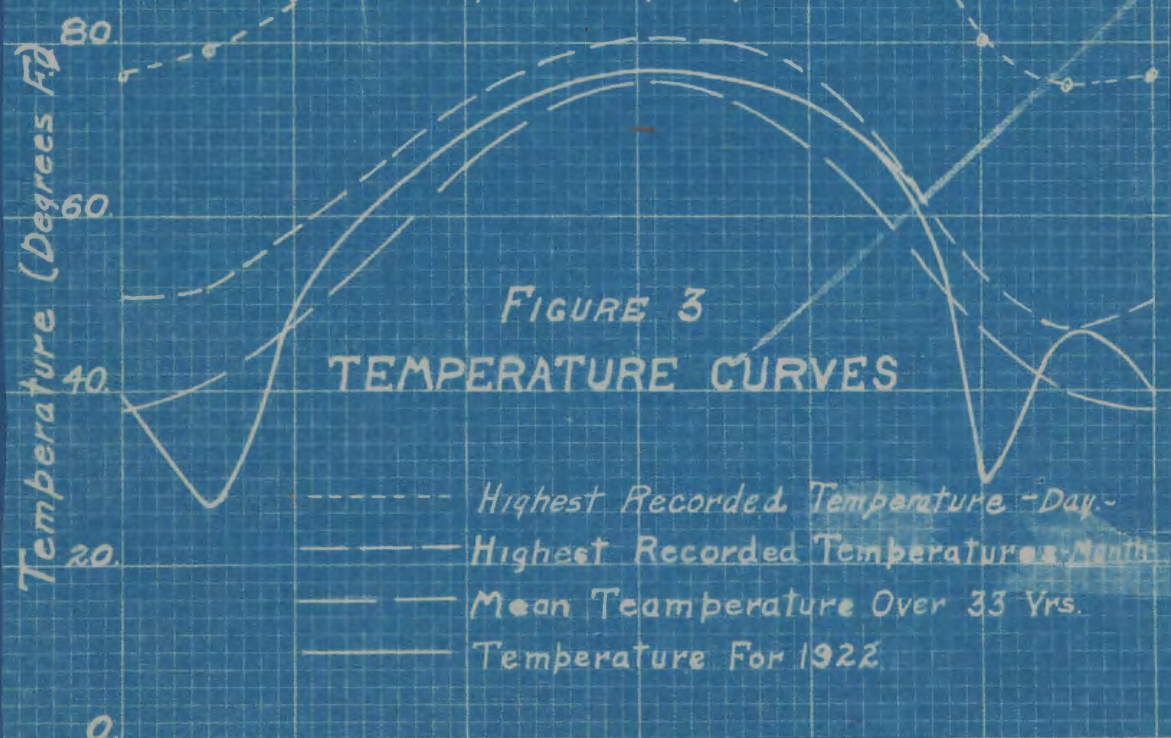
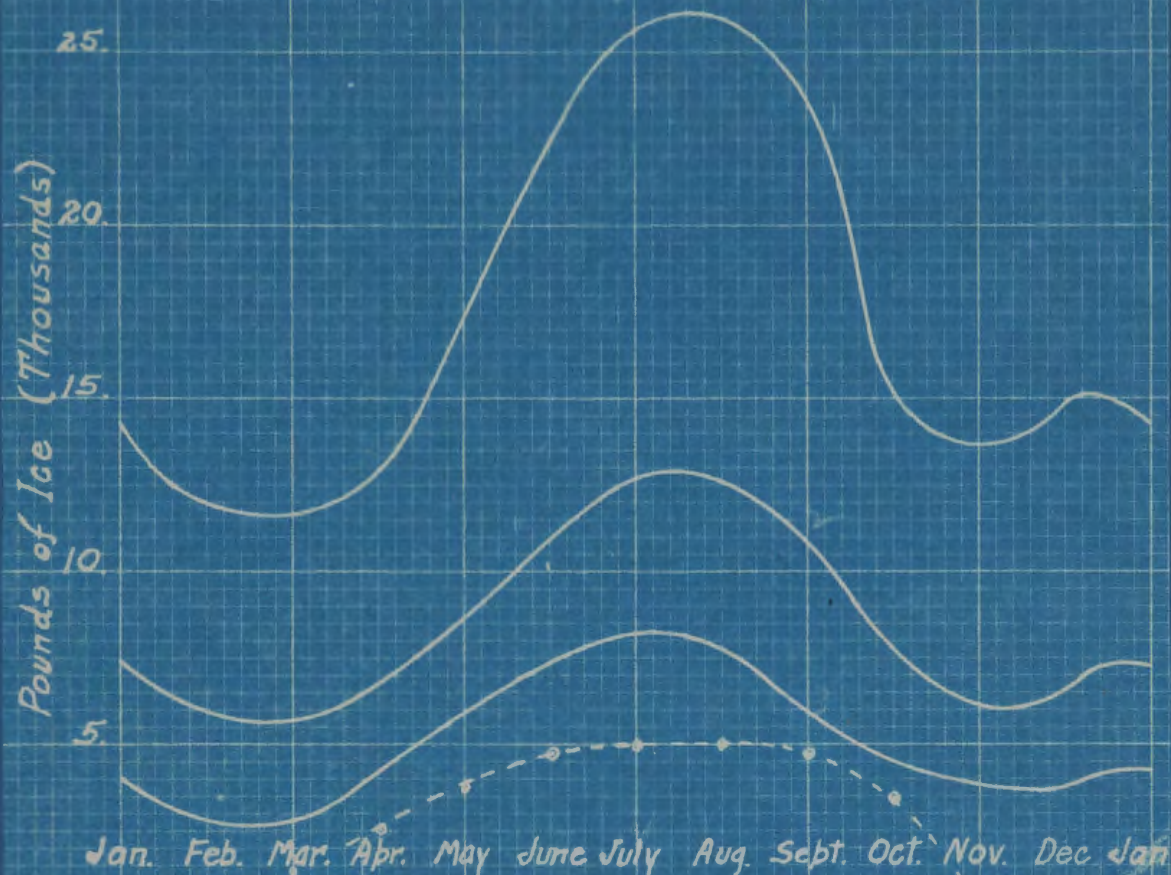
In any central plant system the direct expansion method is more advisable, when possible to install. In the first place the overall efficiency with direct expansion is much higher than the brine circulation method, and consequently requires less horse power per ton of refrigeration. Then again the radiation losses with the brine system are about twice those of the direct expansion unit. The upkeep of the direct

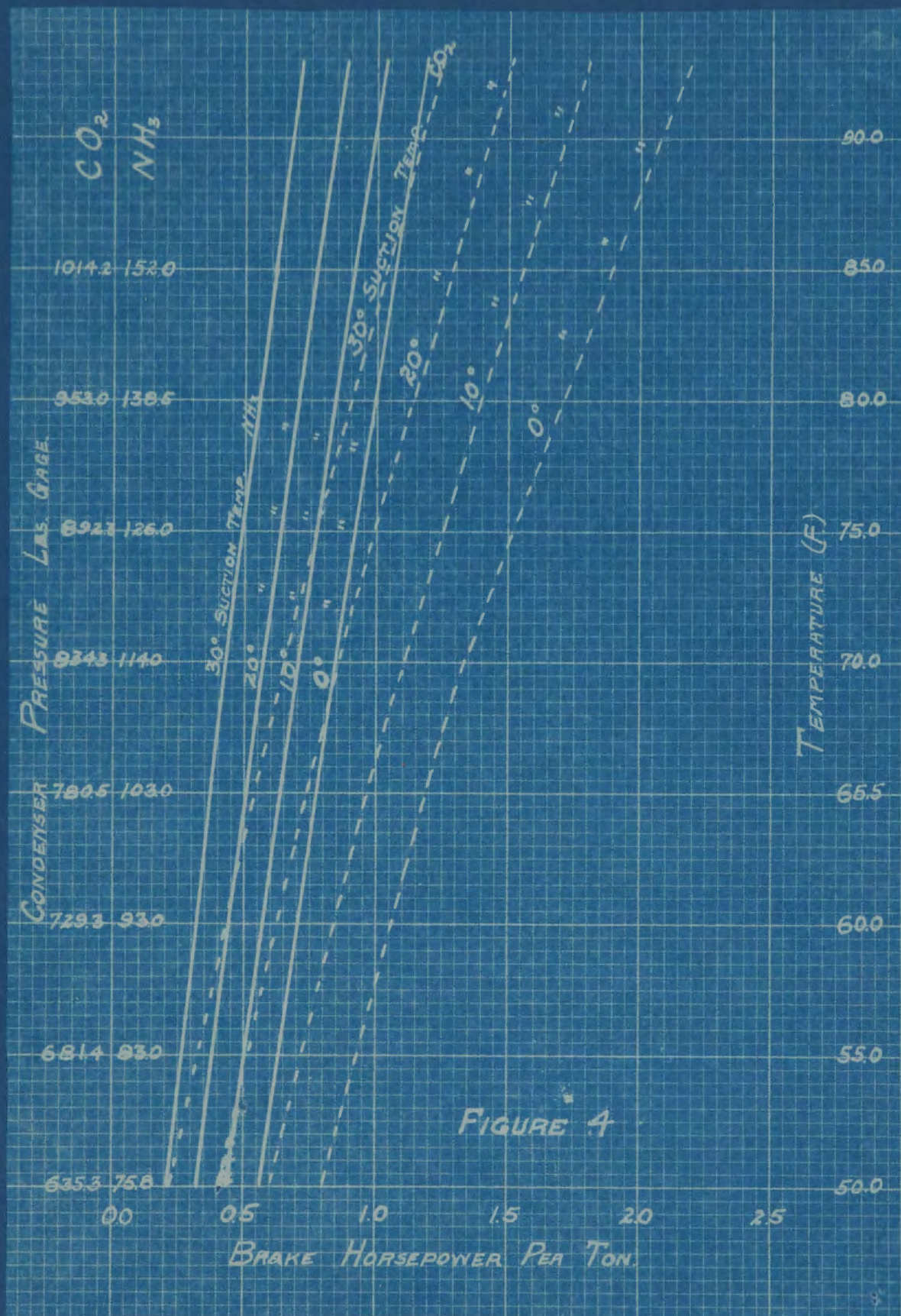


PROPERTIES  
of  
VARIOUS  
REFRIGERANTS  
FIGURE 2.

|                                | ETHYL ALCOHOL    | CARBON TETRACLD. | ETHYL IODIDE | HEXANE      | CARBON DISULPHIDE | PENTANE     | ETHER.      | BUTANE      | CARBON DIOXIDE | AMMONIA | SULPHUR DIOXIDE |
|--------------------------------|------------------|------------------|--------------|-------------|-------------------|-------------|-------------|-------------|----------------|---------|-----------------|
| COLUMN                         | 1                | 2                | 3            | 4           | 5                 | 6           | 7           | 8           | 9              | 10      | 11              |
| CHEMICAL SYMBOL                | $C_2H_6O$        | $CCl_4$          | $C_2H_5I$    | $C_6H_{14}$ | $CS_2$            | $C_5H_{12}$ | $C_4H_{10}$ | $C_4H_{10}$ | $CO_2$         | $NH_3$  | $SO_2$          |
| CRITICAL TEMPERATURE (F)       | -----            | -----            | -----        | -----       | 468.0             | 386.6       | 381.0       | 311.0       | 88.2           | 266.0   | 311.0           |
| CRITICAL PRESSURE              | -----            | 44.9             | -----        | -----       | 78.1              | 34.0        | 37.0        | 37.0        | 77.0           | 115.0   | 79.0            |
| BOILING POINT (F)              | 173.0            | 170.0            | 160.0        | 156.0       | 115.0             | 97.0        | 94.0        | 32.5        | -108.0         | -27.4   | 12.6            |
| MELTING POINT                  | -173.6           | -9.4             | -167.5       | -137.1      | -169.0            | -203.5      | -177.1      | -211.0      | -----          | -----   | -104.6          |
| DENSITY AT 0° C.               | 0.78             | 1.58             | 1.92         | 0.66        | 1.29              | 0.65        | 0.72        | 0.60        | -----          | -----   | 1.44            |
| SPECIFIC VOLUME (32° F)        | -----            | 52.6             | -----        | -----       | 28.3              | -----       | 20.1        | -----       | 0.28           | 9.11    | 3.40            |
| CU. FT. PER LB. AT 0° F.       | -----            | -----            | -----        | -----       | 53.7              | -----       | 38.0        | -----       | -----          | -----   | 7.22            |
| VAPOR TENSION                  | <u>lbs. abs.</u> | 1.3              | 2.40         | 2.9         | 3.2               | 7.30        | 10.6        | 10.9        | 35.1           | -----   | 59.9            |
|                                | <u>IN. VAC.</u>  | 37.4             | 25.0         | 24.2        | 23.7              | 14.5        | 8.7         | 7.6         | -----          | -----   | -----           |
| SUCTION PRES.                  | <u>lbs. abs.</u> | 0.3              | 0.65         | 0.8         | 0.9               | 2.5         | 3.7         | 3.65        | 14.6           | 302.7   | 30.1            |
|                                | <u>IN. VAC.</u>  | 29.5             | 28.7         | 28.4        | 28.2              | 25.0        | 22.8        | 22.7        | 0.2            | -----   | -----           |
| RATIO of COMPRESSION           |                  | 4.3              | 3.7          | 3.6         | 3.5               | 2.94        | 2.87        | 2.98        | 2.48           | 0.19    | 0.98            |
| HEAT OF VAPORIZATION           | -----            | 93.6             | -----        | 162.0       | 162.0             | 164.0       | 169.2       | 167.0       | -----          | 592.1   | 163.6           |
| HEAT OF LIQUID (ABOVE 32°)     | -----            | 9.8              | -----        | 14.4        | 11.7              | 14.4        | 26.4        | 14.4        | -----          | -----   | 24.5            |
| COOLING EFF/CU.FT. CYL. DISPL. | -----            | 83.8             | -----        | 147.6       | 150.3             | 149.6       | 142.8       | 152.6       | 539.0          | 199.0   | 139.1           |

# ICE CONSUMPTION CURVES





expansion system is less than the one using brine, due to the fact that the brine is continually eating the piping away. If the pipes are installed correctly in the direct expansion system, there will be no trouble due to replacing of pipes, nor will there be any great leaks, if any at all.

In consideration of the above observations and summaries the designs of the market house project and central plant system for apartments are made for direct expansion coils. As has been stated, the only comparison to be made is between the central plant system in the apartment house, and the installation of individual automatic refrigerators.

### MARKET HOUSE PROJECT

After carefully observing the arrangement of stalls in the market house of this city, and the particular kind of business carried on by each, actual work was started on a mechanical refrigeration installation project.

First a careful survey was made of the ice consumption of each stall during the past year. Many of these stalls were not capable of giving accurate data on any of their ice except their present month consumption. Where ever it was possible to get figures for the entire year of 1922, they were obtained and from these figures the curves 1, 2, and 3 were plotted. The average yearly consumption was then computed and a ratio obtained between this yearly average and the January consumption in each case. The average of this ratio as worked out for curves on figure 3 was then determined and used as a constant in determining the average annual consumption per stall. The sum of these stall consumptions was then taken as the total average ice required by the market house per year.

Ordinarily the ice consumption varies directly as the outside temperature, but with boxes on the inside of a steam heated building, the temperature usually ranges above 60° F. at all times. Therefore the possibility of an exceptionally low temperature is very remote, however this quantity does vary a little even in the coldest weather. This slight variation has no bearing on the design of the plant. On the other hand, regardless of the location of a box the consumption will vary directly as the temperature. This relation can be shown by reference to the formula for leakage loss through walls of a box:

$$Q = A \times K \times (T_1 - T_2)$$

Where:

- Q = Heat lost through walls.
- A = Area of walls in square feet.
- K = Conductivity of material.
- T<sub>1</sub> = Outside temperature.
- T<sub>2</sub> = Inside temperature.

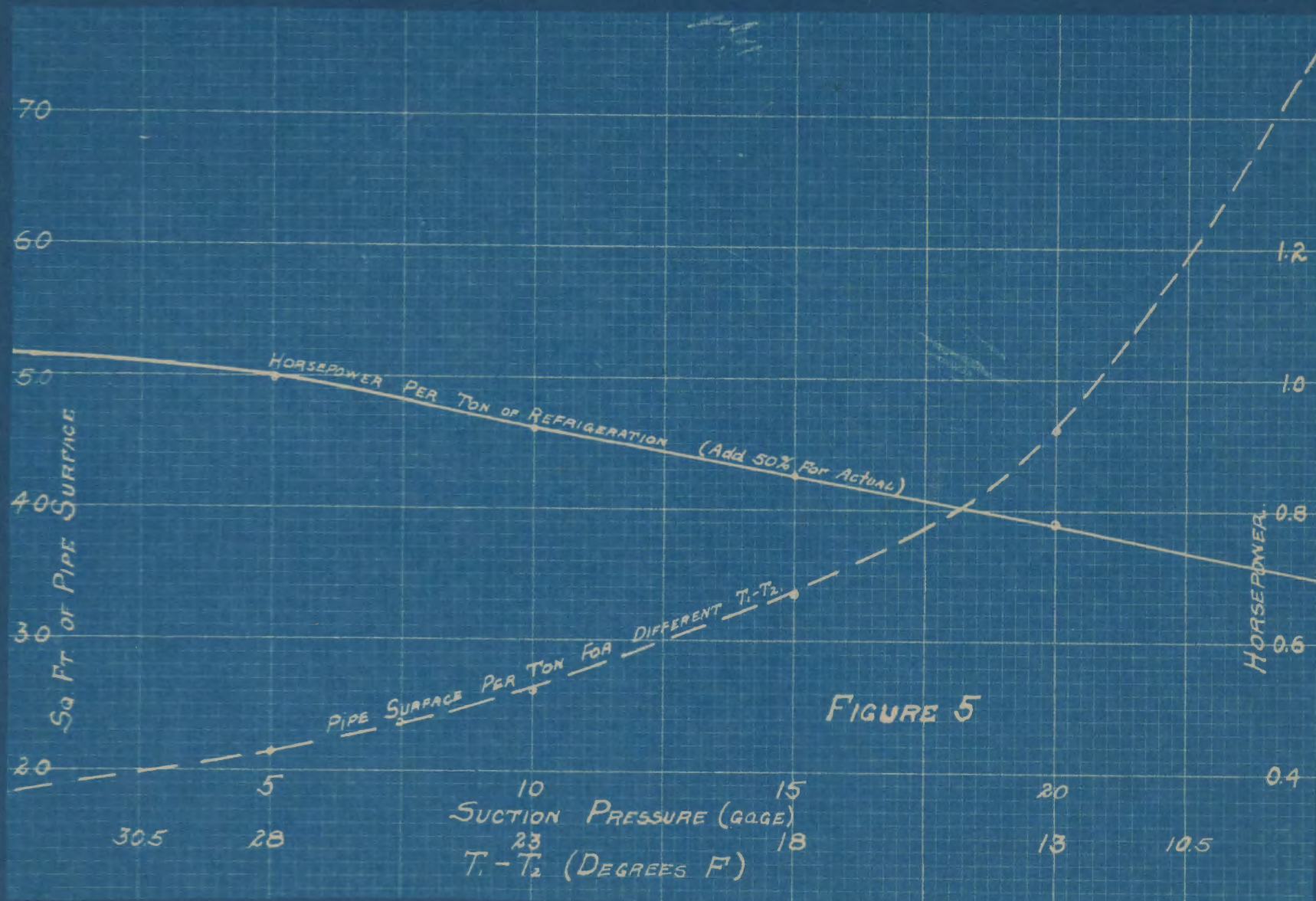
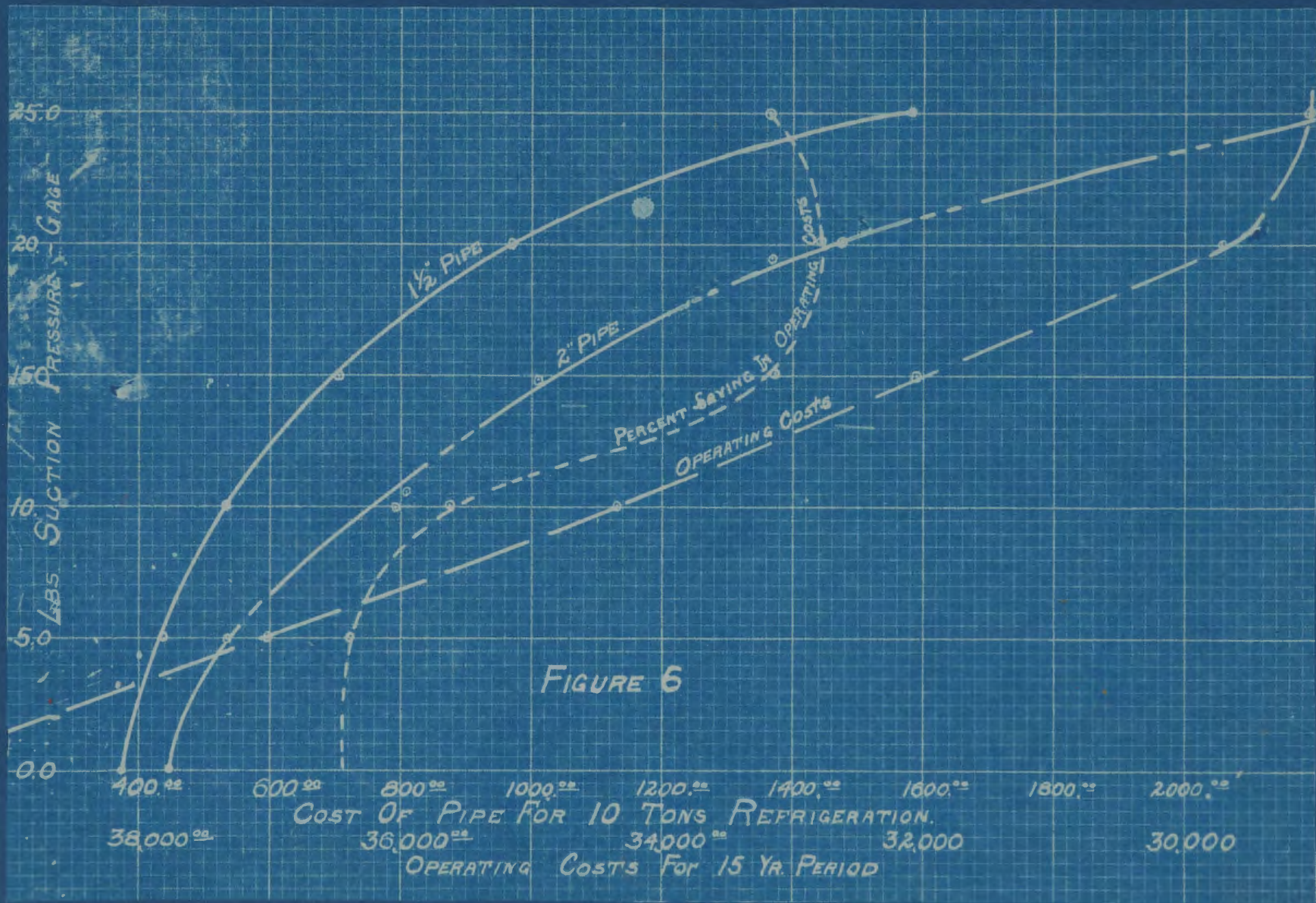


FIGURE 5





Thus for a higher "T," a greater leakage loss is to be expected and with the contents of the box remaining constant, the ice consumption varies as the outside temperature. Another factor also enters in making temperature and consumption vary directly with each other. This is due to the fact that the initial temperature of most all products entering the box depends entirely on outside temperature, and the higher this temperature, the greater the amount of heat to be carried away by the refrigeration unit. Knowing the above mentioned temperature-consumption relation, in order to design a plant capable of carrying all probable loads, a study should be made of local temperature conditions. This is done as described in the following pages.

The average mean monthly temperatures were obtained for the year 1922, and the time-temperature curves plotted. (Note Fig. "3"). On this same curve sheet a curve was drawn representing the average mean monthly temperatures, taken over a period of the last 30 years. Comparisons were made between these curves and the conclusion drawn that the past year was a normal one with respect to temperature. This shows that the output for ice during this year was an average one and in computing the economy of installation and operation, this amount can be taken as the average consumption. The actual amount of money, of course, varies with the price of ice.

In order to compute the theoretical size of the plant, the ratio of the average percent of the highest consumption period, to January consumption, was determined from curves in Fig. "3", and the maximum monthly ice load was computed from the January ice consumption. The ratio of the highest recorded monthly temperature for the past 33 years, to the highest 1922 monthly temperature, was next determined and the size of the plant again increased by the amount so computed. Next the question arises, "Will there ever be a greater demand on the refrigeration system in the future than there is at present?" This increase would be due to either: (a) Additional business of present consumers, (b) Addition of more customers to system, or (c) Any other incidental causes likely to occur.

At present there is no large buildings in the near vicinity of the market house to demand refrigeration, and indications are that there will not be, for at least a good many years. The prospect of enlarging the building to accommodate more stalls is also a very remote one, due to the present limited and congested conditions in and around the market house. Thus the probability of increased consumption from the first mentioned possible cause should not be considered.

The real possibility for increased demand lies largely in the increased business of the present stalls. The chance for this condition to occur is very possible, and considering the present growth of the city, business will most likely increase. Therefore the plant as designed should be increased in size once more. This increase is very indeterminate however,

and can only be approximately computed. The method followed is outlined as follows:

Percentage of increase of each succeeding census over the last one was determined, and from these percentages, together with the percentage of increase during the past three years, the approximate increase of population for the next twenty years determined. At the end of this time if the city continues to grow, the center of business will necessarily be changed, consequently a longer period need not be considered. Assuming that a certain percentage of this increased population traded with the market house concerns, the maximum consumption is again increased by a certain amount.

With maximum demand known, the theoretical size of the installation can be calculated; and by assuming a volumetric efficiency of 80%, with radiation losses equivalent to one half ton of refrigeration, the actual size was determined. The system is designed and laid out as shown in following pages.

#### COMPARISON OF APARTMENT HOUSE REFRIGERATION SYSTEMS.

Refrigeration for apartments is, as previously stated, a project just coming into practical and economic use. Study, comparatively speaking, has just begun on the question and the field is a very large one. In years to come there is no doubt but what every apartment will be equipped with refrigeration systems, and those not so designed will be at a disadvantage in competing with others so equipped.

The question arises as to which system of refrigeration is the most efficient and convenient, as well as being an economic investment. The ice delivery system, no doubt ranks last place in considering convenience alone, while the other systems are practically on the same plane with each other. Naturally the manufacturers of the separate units insist upon their systems as being the most economic and advisable, while the central plant people stand strongly behind their installations. There are arguments for and against each system and these will be considered in attempting to arrive at a conclusion as to the comparative economy of each unit.

The manufacturers of the "Kelvinator" and "Frigidaire" units are working hard to get their units into, not only apartments, but private homes as well. They have been to some extent, successful in this and at present there are, in this city alone, over fifty installations. And in most every one of these installations satisfaction is being obtained by the owners. They all express their feelings of relief in having no ice question to worry about, or ice man to contend with. The only thought of the refrigeration question occurs when the water and electric bills are presented at the end of each month. Then in many cases, this cost does not equal the price previously paid for ice during the same period. The average person is willing

to let the operating costs of the automatic system even exceed that of the ice delivery method in order to eliminate one of the big and constant troubles of the modern phase of house keeping.

The initial cost of these units is the one prohibitive factor to many otherwise prospective buyers and owners, consequently the field is to some extent a limited one. The economy of investment and cost of operation though are the prime objects in the apartment house projects, for the central plant as well as the separate unit installations. They must prove themselves to be of economic value to the owner of the apartment as well as a convenience to the occupants, before the average business man will consider the question of installation. In order to determine the financial economic value of the three systems, disregarding the convenience factor, a number of possible cases have been assumed and the actual cost of operation for each method, under each assumption, computed for a period of one years use. In each case, for purposes of comparison, the assumption is made that the consumer uses the refrigerator during the entire year with a constant load equivalent to the melting of 50 pounds of ice per day.

#### CASE I

##### SINGLE INSTALLATIONS

#### 1. Ice delivered:

Price of ice: 60 cents per 100 pounds.

Cost of refrigerator: \$200.00

#### Operating Cost.

Ice consumed per year:-----\$108.00

Depreciation at 10% ----- 20.00

Interest on investment: ---- 12.00

Total cost of using delivered ice: \$140.00

#### 2. Separate unit. (Frigidaire)

Cost of "B-9" unit, delivered: \$295.00

Cost of refrigerator: 200.00

Total cost of installation: \$495.00

#### Operating Cost.

Power: 7 cents per Kw. Hr. \$44.80

Water: Estimated :----- 10.00

Depreciation at 10%: ----- 49.50

Interest on investment: ---- 29.70

Repairs: Estimated. ----- 5.00

Total cost of using "Frigidaire" ---\$139.00

## 3. Separate unit. (Kelvinator)

|                                 |                 |
|---------------------------------|-----------------|
| Cost of "6-10" unit, delivered: | \$275.00        |
| Cost of refrigerator:           | 200.00          |
| Total cost of installation:     | <u>\$475.00</u> |

## Operating Cost.

|                                        |                 |
|----------------------------------------|-----------------|
| Power: 7 cents per Kw. Hr. -----       | \$43.80         |
| Depreciation at 10%: -----             | 47.50           |
| Interest on investment at 6%: -----    | 28.50           |
| Repairs: Estimated. -----              | 5.00            |
| Total cost of using "Kelvinator" ----- | <u>\$124.00</u> |

The above computations are only for purposes of comparison of the single units and their respective operating costs per year. Note should be made that both of the automatic units show a lower operating cost than the system using the ice delivery plan.

## CASE II

-----  
INSTALLATION FOR 30 SUITE APARTMENT.

## 1. Ice delivered:

|                                               |
|-----------------------------------------------|
| Price of ice: 60 cents per 100 pounds.        |
| Initial cost of refrigerators: \$200.00 each. |
| Cost of 30 refrigerators: \$6,000.00          |

## Operating Cost.

|                                          |                   |
|------------------------------------------|-------------------|
| Ice consumed per year: -----             | \$3,240.00        |
| Depreciation at 10%: -----               | 600.00            |
| Interest on investment at 6%: -----      | 360.00            |
| Total cost of using delivered ice: ----- | <u>\$4,200.00</u> |

Cost per suite: \$140.00

## 2. Central plant:

|                             |                   |
|-----------------------------|-------------------|
| Cost of 4 ton installation: | \$8,000.00        |
| Cost of 30 refrigerators:   | Included above.   |
| Total cost of installation: | <u>\$8,000.00</u> |

## Operating Cost.

|                                          |                   |
|------------------------------------------|-------------------|
| Power: 5 cents per Kw. Hr. -----         | \$1,180.00        |
| Water: 14 cents per 1000 gals. -----     | 350.00            |
| Depreciation at 10%: -----               | 800.00            |
| Interest on investment at 6%: -----      | 480.00            |
| Refrigerant per year: -----              | 50.00             |
| Rent of basement room: -----             | 600.00            |
| Engineer at one quarter time: -----      | 300.00            |
| Repairs: Estimated. -----                | 300.00            |
| Total cost of using central plant: ----- | <u>\$3,960.00</u> |

Cost per suite: \$132.00

## 3. Separate unit: (Frigidaire)

|                                          |                    |
|------------------------------------------|--------------------|
| Cost of 30 "B-9" units, delivered:       | \$9,450.00         |
| Cost of 30 refrigerators:                | 6,000.00           |
| Total cost of "Frigidaire" installation: | <u>\$15,450.00</u> |
| Less 2% for bulk order:                  | 309.00             |
| Net cost of installation:                | <u>\$15,041.00</u> |

## Operating Cost.

|                                        |                   |
|----------------------------------------|-------------------|
| Power: 5 cents per Kw. Hr. -----       | \$ 960.00         |
| Depreciation at 10%: -----             | 1,504.00          |
| Interest on investment at 6%: -----    | 927.00            |
| Water: 14 cents per 1000 gals. ----    | 350.00            |
| Repairs: Estimated. -----              | 150.00            |
| Total cost of using "Frigidaire" ----- | <u>\$3,891.00</u> |

Cost per suite: \$131.00

## 4. Separate unit: (Kelvinator)

|                                          |                    |
|------------------------------------------|--------------------|
| Cost of 30 "6-10" units, delivered:      | \$8,250.00         |
| Cost of 30 refrigerators:                | 6,000.00           |
| Total cost of "Kelvinator" installation: | <u>\$14,250.00</u> |
| less 2% for bulk order:                  | 285.00             |
| Net cost of installation:                | <u>\$13,965.00</u> |

## Operating Cost.

|                                         |                   |
|-----------------------------------------|-------------------|
| Power: 5 cents per Kw. Hr. -----        | \$ 960.00         |
| Depreciation at 10%: -----              | 1,397.00          |
| Interest on investment at 6%: -----     | 835.00            |
| Repairs: Estimated. -----               | 150.00            |
| Total cost of using "Kelvinators" ----- | <u>\$3,342.00</u> |

Cost per suite: \$114.70

## CONCLUSION ON 30 SUITE APARTMENT HOUSE INSTALLATION

For the 30 suite apartment with costs as computed above, no definite conclusion can be drawn. However the results seem to indicate a decision in favor of the "Kelvinator" installation. The initial costs vary from about \$6,000.00 to \$16,000.00, which of course is an item of consideration to the owner. Interest however has been computed at 6% on the investment in each case, and the correct figures to use for a comparison should be the operating costs as computed. Referring to these figures, the first observation is that the ice delivery system, which involved the least investment, costs the most per suite per year. Not only does it cost the most financially to them and the owner, but causes much dissatisfaction as well. This dissatisfaction, although not reflected upon the owner in any way, indirectly causes the occupants much worry and this worry is associated with the particular apartment. Thus the poor ice service effects the occupants of apartments in such a manner that in some cases causes them to move to another place.

The owner should, by all means, take steps to remedy this trouble if it happens to exist in the apartment.

A slight addition to the first mentioned investment will install the central plant system. This system, at present is in a stage of rapid development, but under correct supervision can be installed to give excellent satisfaction. By shifting to the central plant installation the responsibility is transferred to the engineer in charge of the unit, and in this manner many of the minute details and complaints would never get to the owner. On the other hand the occupants would most likely be willing to endure an occasional unpleasantness if they knew that they could depend upon their ice supply without having to bother about the ice man every day.

The third possibility for refrigeration of the apartment would be the installation of a separate unit in each suite. This system would remove the ice question farther than ever from the owner, for in this case each suite would take care of its own unit. That is to say, the occupants would have their own individual unit for their suite. The only attention which these units would ordinarily need would be an annual inspection and oiling. The operating costs as computed in case II allow for all units to be on the line current, with the operating costs and fixed charges included in the suite rentals.

In this last mentioned consideration there are two distinct units to choose between. The "Frigidaire" unit, (Figures 9, 10, 11,) is the older of the two types and from all indications is slightly more expensive, both from the standpoint of initial investment and operating costs. The compact machine is a very desirable feature in favor of this unit and might in some cases overcome the financial objection. The water rate, though is very indefinite and may go above the figures allowed in the cost data as given above. The "Kelvinator" is the other type of automatic unit, (Figures 12 and 13) and seems to have a good future before it. Requiring no condensing water and the same amount of current as the "Frigidaire", the operating costs are consequently much lower. The initial cost of the "Kelvinator" is \$475.00 while the "Frigidaire" sells for \$515.00. Thus the operating costs of the "Kelvinator" are again lower than those of the "Frigidaire" due to the lower depreciation charge and interest on investment. The "Kelvinator" has the undesirable feature of having the compressor unit on a separate and distinct base from the refrigerator box. The cellar, of course, is a very convenient place for this unit, but with the apartment project the conditions are much different. However, this feature is not so undesirable as at first might appear, for each compressor unit could conveniently be hung from the back porch ceiling, where it would be out of the way and at the same time be in a well ventilated place.

By referring to the operating costs of each unit, the writer's opinion is that the owner of the 30 suite apartment

would most likely decide upon the "Kelvinator" as the most economical unit. There are of course other factors which would enter into the decision, thereby making it practically impossible to reach any definite conclusion regarding the general apartment house projects.

### CASE III

#### ----- INSTALLATION FOR 60 SUITE APARTMENT

##### 1. Ice delivered:

Price of ice: 60 cents per 100 pounds.  
Initial cost of refrigerators: \$200.00 each.  
Cost of 60 refrigerators: \$12,000.00

##### Operating Cost

|                                        |                   |
|----------------------------------------|-------------------|
| Ice consumed per year: -----           | \$6,480.00        |
| Depreciation at 10%: -----             | 1,200.00          |
| Interest on investment at 6%: ----     | 720.00            |
| Total cost of using delivered ice: --- | <u>\$8,400.00</u> |

Cost per suite: \$140.00

##### 2. Central plant:

Cost of 6 ton installation: \$13,000.00

##### Operating Cost.

|                                        |                   |
|----------------------------------------|-------------------|
| Power: 5 cents per Kw. Hr. -----       | \$1,500.00        |
| Water: 14 cents per 1000 gals: --      | 500.00            |
| Depreciation at 10%: -----             | 1,300.00          |
| Interest on investment at 6%: ----     | 780.00            |
| Refrigerant per year: -----            | 100.00            |
| Rent of basement floor: -----          | 600.00            |
| Engineer at one quarter time: ----     | 300.00            |
| Repairs: Estimated. -----              | 600.00            |
| Total cost of using central plant: --- | <u>\$5,680.00</u> |

Cost per suite: \$94.70

##### 3. Separate unit: (Frigidaire)

|                                          |                    |
|------------------------------------------|--------------------|
| Cost of 60 "B-9" units, delivered:       | \$18,000.00        |
| Cost of 60 refrigerators:                | 12,000.00          |
| Total cost of "Frigidaire" installation: | <u>\$30,000.00</u> |
| Less 4% for bulk order:                  | 1,236.00           |
| Net cost of installation:                | <u>\$29,664.00</u> |

## Operating Cost.

|                                       |                   |
|---------------------------------------|-------------------|
| Power: 5 cents per Kw. Hr. -----      | \$1,920.00        |
| Depreciation at 10%: -----            | 2,966.00          |
| Interest on investment at 6%: ----    | 1,780.00          |
| Water: 14 cents per 1000 gals: --     | 500.00            |
| Repairs: Estimated. -----             | 300.00            |
| Total cost of using "Frigidaire": --- | <u>\$7,466.00</u> |

Cost per suite: \$124.20

## 4. Separate unit: (Kelvinator"

|                                          |                    |
|------------------------------------------|--------------------|
| Cost of 60 "6-10" units, delivered:      | \$16,500.00        |
| Cost of 60 refrigerators:                | 12,000.00          |
| Total cost of "Kelvinator" installation: | <u>\$28,500.00</u> |
| Less 4% for bulk order:                  | 1,140.00           |
| Net cost of installation:                | <u>\$27,360.00</u> |

## Operating Cost.

|                                          |                   |
|------------------------------------------|-------------------|
| Power: 5 cents per Kw. Hr. -----         | \$1,920.00        |
| Depreciation at 10%: -----               | 2,736.00          |
| Interest on investment at 6%: -----      | 1,710.00          |
| Repairs: Estimated. -----                | 300.00            |
| Total cost of using "Kelvinators": ----- | <u>\$6,640.00</u> |

Cost per suite: \$110.60

## CASE IV

-----  
INSTALLATION FOR 90 SUITE APARTMENT

## 1. Ice delivered:

|                                               |             |
|-----------------------------------------------|-------------|
| Price of ice: 60 cents per 100 pounds.        |             |
| Initial cost of refrigerators: \$200.00 each. |             |
| Cost of 90 refrigerators:                     | \$18,000.00 |

## Operating Cost.

|                                          |                    |
|------------------------------------------|--------------------|
| Ice consumed per year: -----             | \$9,720.00         |
| Depreciation at 10%: -----               | 1,800.00           |
| Interest on investment at 6%: -----      | 1,080.00           |
| Total cost of using delivered ice: ----- | <u>\$12,600.00</u> |

Cost per suite: \$140.00

## 2. Central plant:

Cost of 7 ton installation: \$18,000.00

## Operating Cost.

|                                          |                   |
|------------------------------------------|-------------------|
| Power: 5 cents per Kw. Hr. -----         | \$2,000.00        |
| Water: 14 cents per 1000 gals: -----     | 700.00            |
| Depreciation at 10%: -----               | 1,800.00          |
| Interest on investment at 6%: -----      | 1,080.00          |
| Refrigerant per year: -----              | 100.00            |
| Rent of basement room: -----             | 600.00            |
| Engineer at one quarter time: -----      | 300.00            |
| Repairs: Estimated. -----                | 700.00            |
| Total cost of using central plant: ----- | <u>\$7,280.00</u> |

Cost per suite: \$80.90

## 3. Separate unit: (Frigidaire)

|                                          |                    |
|------------------------------------------|--------------------|
| Cost of 90 "B-9" units, delivered: --    | \$28,350.00        |
| Cost of 90 refrigerators:                | <u>18,000.00</u>   |
| Total cost of "Frigidaire" installation: | <u>\$46,350.00</u> |
| Less 6% for bulk order:                  | <u>2,780.00</u>    |
| Net cost of installation: -----          | <u>\$43,570.00</u> |

## Operating Cost.

|                                         |                    |
|-----------------------------------------|--------------------|
| Power; 5 cents per Kw. Hr. -----        | \$2,880.00         |
| Depreciation at 10%: -----              | 4,357.00           |
| Water: 14 cents per 1000 gals: -----    | 700.00             |
| Interest on investment at 6%: -----     | 2,619.00           |
| Repairs: Estimated. -----               | 500.00             |
| Total cost of using "Frigidaire": ----- | <u>\$11,056.00</u> |

Cost per suite: \$122.80

## 4. Separate unit: (Kelvinator)

|                                          |                    |
|------------------------------------------|--------------------|
| Cost of 90 "6-10" units, delivered:      | \$24,750.00        |
| Cost of 90 refrigerators:                | <u>18,000.00</u>   |
| Total cost of "Kelvinator" installation: | <u>\$42,750.00</u> |
| Less 6% for bulk order:                  | <u>2,565.00</u>    |
| Net cost of installation: -----          | <u>\$40,185.00</u> |

## Operating Cost.

|                                          |                   |
|------------------------------------------|-------------------|
| Power: 5 cents per Kw. Hr. -----         | \$2,880.00        |
| Depreciation at 10%: -----               | 4,018.00          |
| Interest on investment at 6%: -----      | 2,411.00          |
| Repairs: Estimated. -----                | 500.00            |
| Total cost of using "Kelvinators": ----- | <u>\$9,809.00</u> |

Cost per suite: \$109.00

## CONCLUSIONS ON 60 AND 90 SUITE APARTMENT HOUSE INSTALLATIONS

The results of the above computations are shown in graphical form in Figure "8". By referring to the curves on this figure, the economy of the central plant in large installations is clearly demonstrated. Thus the conclusion is drawn that for smaller installations of only a few units, the separate automatic system is a little more economical than the ice delivery system. By comparison of the two separate units, the "Kelvinator" shows a much lower operating cost than the "Frigidaire" and consequently shows up much better in the comparative rating as given by the curves in Figure "8".

No doubt but that the separate unit installation is advisable in some cases, but for the general apartment house project the central plant system has proved itself to be the most economical and efficient. Many concerns and people do not favor the central installation on account of various objections, the principle ones of which will be taken up and discussed in the following paragraph. In each case the writer will attempt to determine the weight of the objection, and if possible, arrive at a solution for the same.

Arguments against the central plant installation are as follows:

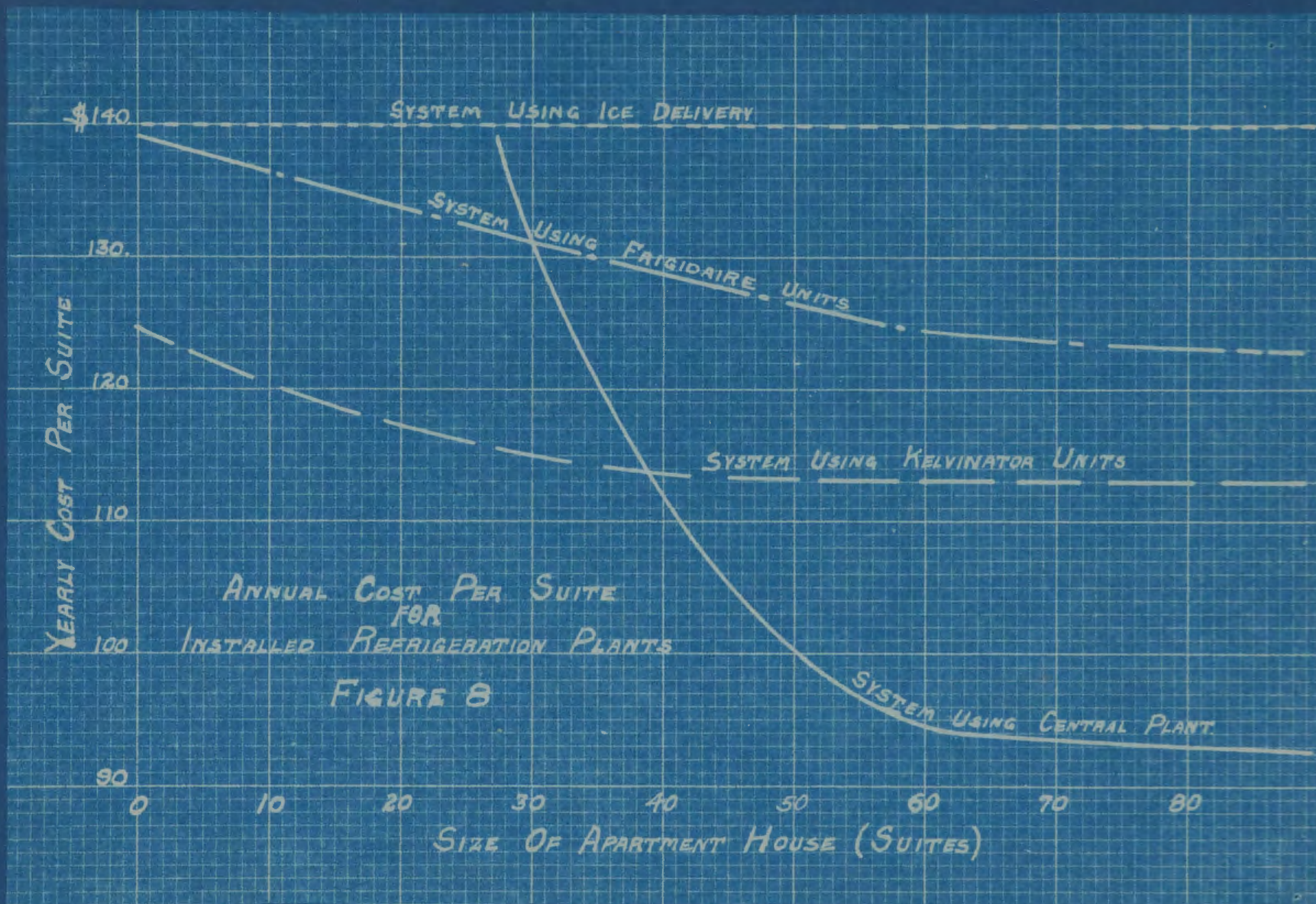
1. Pipe chases between the walls are necessary, and the arrangement and location of these chases effects the entire layout of the building.
2. These chases occupy valuable space and are an expense to construct.
3. Cellar space occupied by unit is usually very valuable.
4. Engineer's services are required with the central plant even it is of the automatic type.
5. The central plant is part of the building and later changes are most always impractical.
6. Ice usually has to be obtained from basement and this causes much trouble to all concerned.
7. Breakdowns will inconvenience the entire apartment instead of just the individual.
8. Not having to pay for refrigeration according to the amount used, the consumer will be more wasteful with the cooling unit.
9. Leaks in pipe lines are very difficult to repair.
10. Pipes in walls cause walls to sweat and become discolored.
11. Ammonia gas is very poisonous and is a menace to the lives of the people in the apartment.
12. Explosion of ammonia lines is another possibility which again endangers the lives of the occupants.

The writer's opinion is that for each of the above arguments there is a solution, which in each case more than outweighs the objection to the central plant installation. These solutions are respectively as follows:

1. Usually the apartment can be arranged so that the chases will be conveniently located, without changing or interfering with the design of the apartment. Note the diagram of the "Denifer Apartments", on Fig. "11".
2. The space taken up by the chases is not enough to amount to an appreciable quantity, and the cost of installation and construction has been added into the figures as given in above computed yearly costs.
3. Rent for this space has been provided for in yearly cost of operation and use.
4. The salary of the engineer on part time has been provided for the yearly cost of operation and use.
5. Changes in the design of the building would have to be very fundamental to effect the design of the pipe chases. Depreciation has been allowed in above computations at the rate of 10%. The possibility of any building being remodeled within ten years after construction, is very remote.
6. In the modern direct expansion system this condition does not exist as each individual refrigerator makes at least five pounds of ice per day.
7. The factor of safety has been taken at such a large figure in the design of the modern system that the possibility of breakdowns are very few.
8. If tendency is to waste the refrigerating effect a device may be installed in each line to measure the individual consumption.
9. These leaks are not very numerous due to the high factor of safety used in the design of the piping system.
10. In the modern installation this condition does not exist due to the excellent methods used in insulation of the pipe lines.
11. Great precaution is taken in the installation of the pipe lines and the possibility of gas escaping is very remote. When this leakage does occur the gas is taken to the atmosphere above the roof by vents constructed for that purpose.
12. There is no danger from explosion of ammonia lines in the modern installation of the direct expansion system.

A final consideration of all costs and conditions of operation for each of the possible methods of refrigeration, should show the comparative ratings of each system. By making these comparisons of cost and operating factors, including installation problems and others characteristic of each system, the conclusion of the writer regarding the comparative advisability of each proposed apartment installation is expressed in the ratings listed as follows:

- First: Central plant installation.
- Second: Separate unit installation using "Kelvinators".
- Third: Separate unit installation using "Frigidaire".
- Fourth: Individual refrigerators using delivered ice.



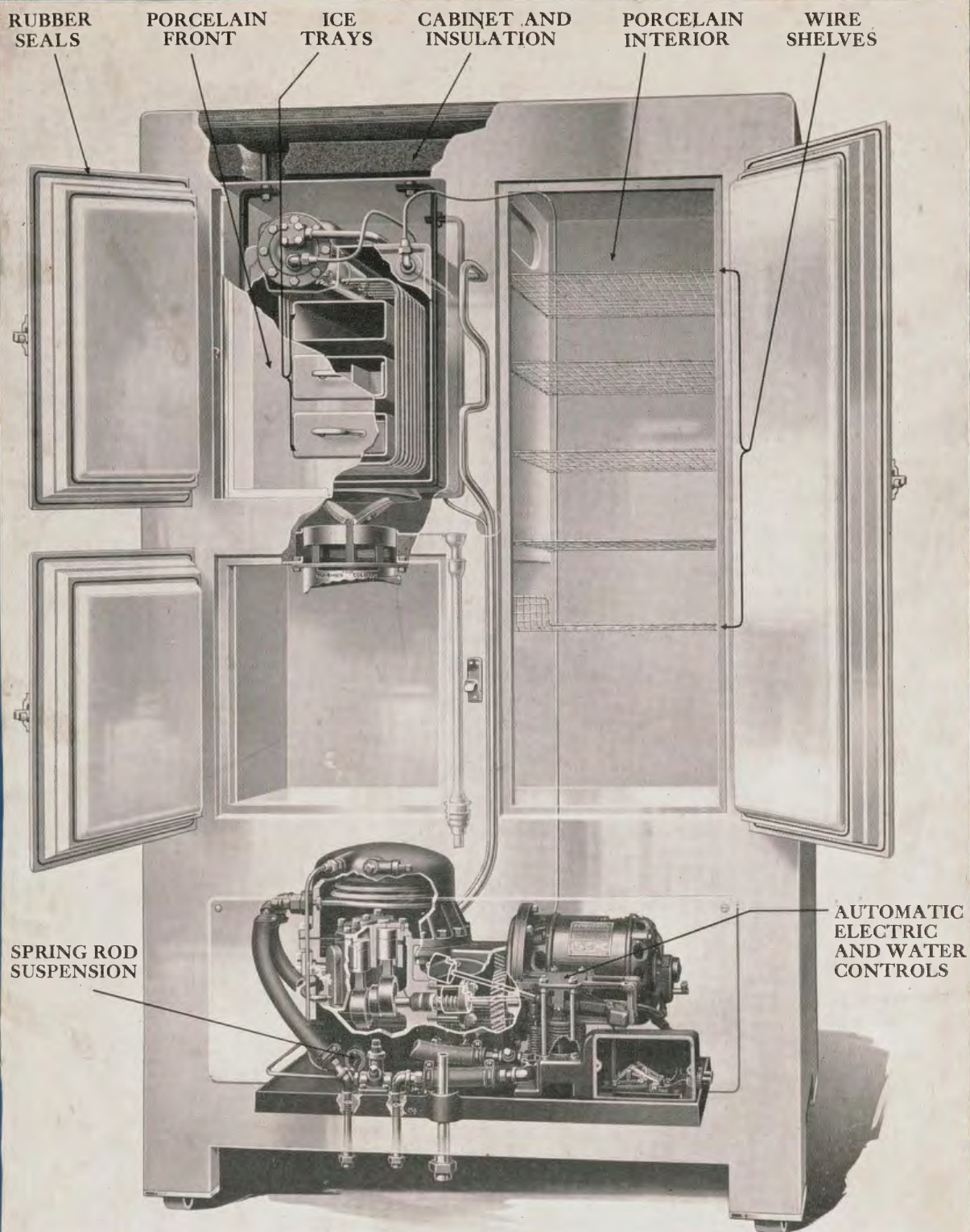
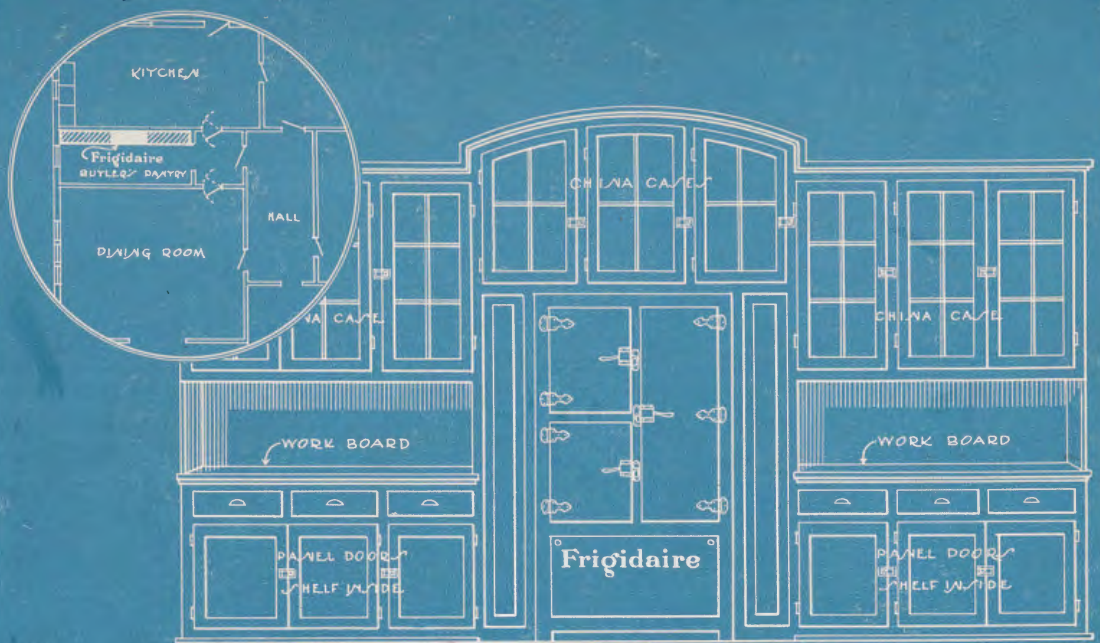


FIGURE 9  
SECTION VIEW MODEL B-9

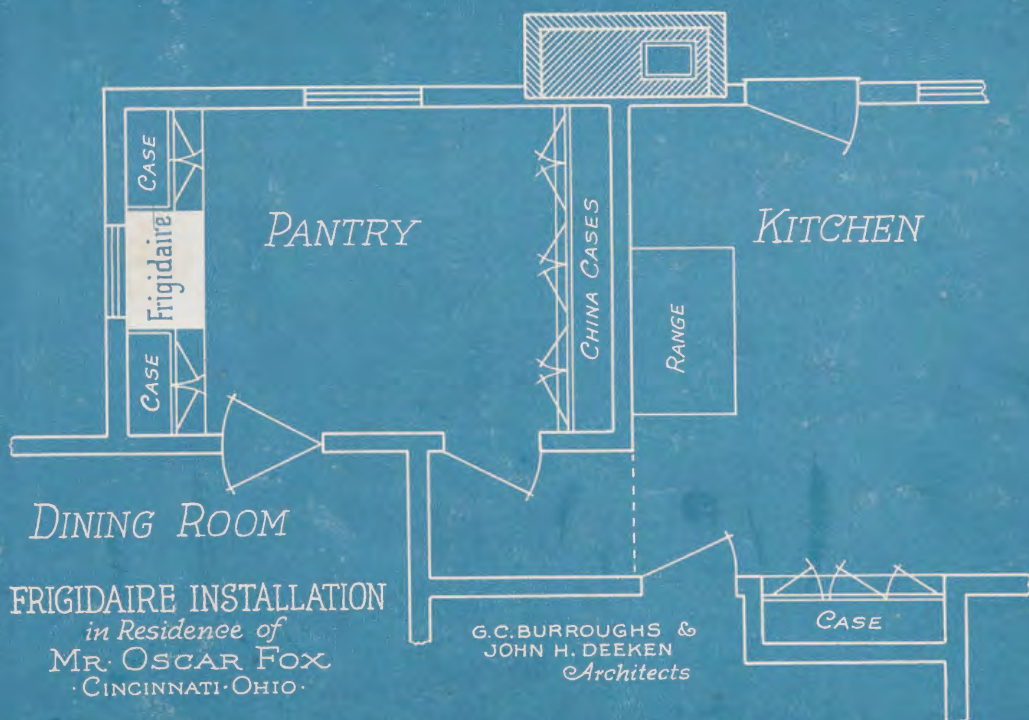




DRAWING OF FRIGIDAIRE BUILT INTO BUTLER'S PANTRY.

## TYPICAL INSTALLATIONS

### FIGURE 10



Automatic Temperature  
Control—No Variation

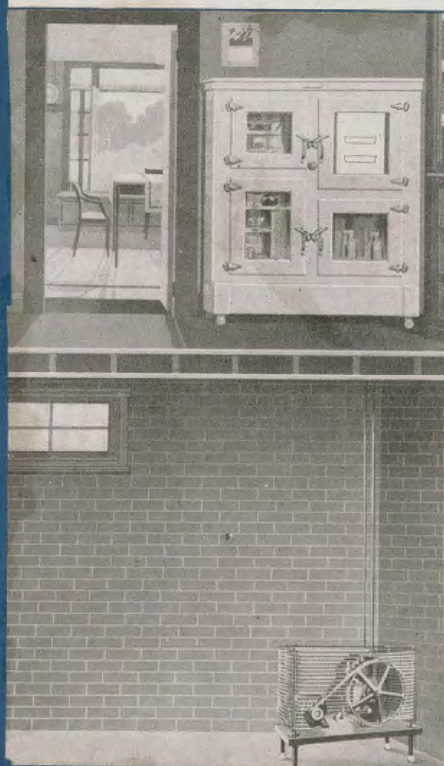
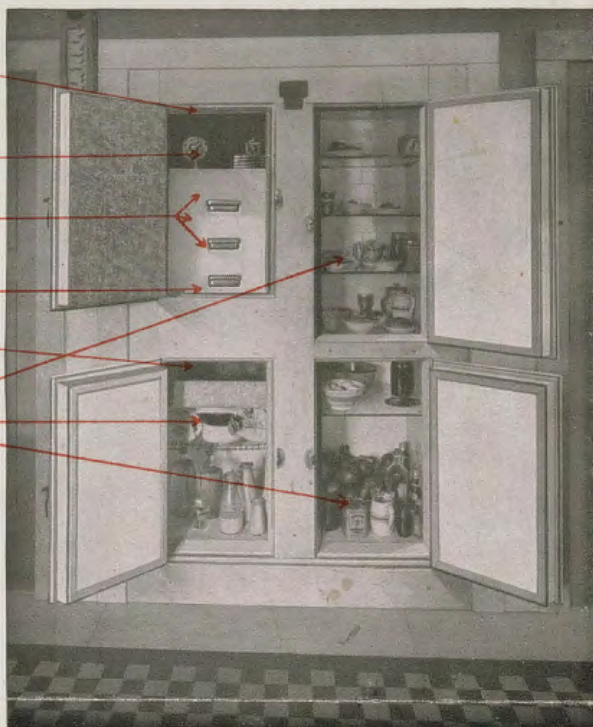
Colder Than Ice—  
Never Melts

Cubes of Pure Ice  
for Table Use

Fits Your Own Refrigerator

No Drip or Slime—  
Clean and Sanitary

Food Preserved and  
Protected by Dry Cold—  
Ideal Refrigeration



KELVINATOR UNIT  
FIGURE 12

ICE USED BY STALLS IN MARKET HOUSE DURING MONTH OF  
JANUARY, 1923.

( NUMBERS REFER TO LOCATION ON FIGURE 7. )

|                         |      |             |
|-------------------------|------|-------------|
| L. Lippner.             | 1-R  | 29,000 Lbs. |
| Palace Fish Market.     | 2-R  | 6,000 "     |
| G. J. Renegar.          | 3-R  | 14,300 "    |
| John Horne.             | 4-R  | 2,100 "     |
| McNutt Floral Co.       | 5-R  | 2,400 "     |
| Economy Meat Market.    | 6-R  | 4,900 "     |
| R. W. Pierce.           | 9-R  | 1,500 "     |
| Turner Grocery.         | 9-R  | 2,200 "     |
| J. W. Schaufer.         | 10-R | 1,400 "     |
| Az Saterfield.          | 11-R | 12,500 "    |
| Knight & Kirby.         | 12-R | 16,050 "    |
| A. L. Dossett.          | 12-R | 4,500 "     |
| Thompson & McClannahan. | 13-R | 4,500 "     |
| J. C. Carey.            | 14-R | 3,000 "     |
| J. A. Bowman.           | 1-L  | 18,500 "    |
| G. H. Donehue.          | 2-L  | 7,300 "     |
| Fruit Stall.            | 3-L  | 1,300 "     |
| H. O. Lewis.            | 4-L  | 2,650 "     |
| O. S. Erwin.            | 5-L  | 2,000 "     |
| Small Grocery Stall.    | 5-L  | 1,500 "     |
| Davis Bros.             | 6-L  | 3,600 "     |
| S. H. Plemons.          | 7-L  | 5,000 "     |
| H. B. Jones.            | 8-L  | 2,000 "     |
| Market House Creamery.  | 10-L | 6,000 "     |
| B. P. Flennilen.        | 11-L | 700 "       |
| H. S. Maxey.            | 12-L | 3,100 "     |
| Dossett & Hackney.      | 13-L | 7,500 "     |
| Crouch Stall.           | 14-L | 8,000 "     |
| Haynes & Knight.        | 15-L | 4,100 "     |
| D. B. Cawood.           | 15-L | 3,900 "     |
| S. B. Abbott.           | 16-L | 2,500 "     |

## COMPUTED MAXIMUM MONTHLY ICE LOAD

Total January consumption: 180,200 Lbs.

Average monthly ice for year in percent of January ice:

Curve 1, Figure 3: ----- 1.22%  
 Curve 2, Figure 3: ----- 1.13%  
 Curve 3, Figure 3: ----- 1.22%

Average monthly ice for year on the average curve equal 1.18%  
 of January ice consumption.

Total monthly average for year:  $180,200 \times 1.18 = 212,650\#$

Average temperature for 1922:  $57.65^{\circ}$  F.

Yearly average for past 33 years:  $57.0^{\circ}$  F.

Thus the average annual consumption in 1922 is equal to the computed average annual consumption for a long period of time, all other conditions being equal.

Maximum ice consumption period on curves of Fig. "3":

Curve 1: -- 1.83% of January ice.  
 Curve 2: -- 1.73% of January ice.  
 Curve 3: -- 2.00% of January ice.

Average maximum period of year: 1.86% of January consumption.

Maximum monthly ice for year:  $180,200 \times 1.86 = 335,200\#$ .

## TEMPERATURE CORRECTION FACTOR

Highest recorded monthly temperature in last 50 years:  $100^{\circ}$  F.

Highest monthly temperature in 1922:  $77.3^{\circ}$  F.

Ratio of above temperatures: 1.294

Assuming that the highest temperature is reached during the period of maximum load, the maximum monthly load after considering temperature factor is:

$1.29 \times 335,200 = 433,750$  Lbs.

## POPULATION CORRECTION FACTOR.

| Period.    | Percentage increase. | Population at end of period. |
|------------|----------------------|------------------------------|
| -----1870  | -----                | 8,680                        |
| 1870--1880 | 11.51%               | 9,690                        |
| 1880--1890 | 130.00%              | 22,530                       |
| 1890--1900 | 45.50%               | 32,346                       |
| 1900--1910 | 11.35%               | 36,346                       |
| 1910--1920 | 114.30%              | 77,818                       |

From the above data it can be observed that the rate of increase has been very uneven. From the percentages of increase so obtained in each period, it is impossible to foretell the growth of the city during the next few years. Since 1920, tho, the population has increased to 98,000 or an increase of approximately 20,000. This would indicate an increase of about 125% each ten years but this rate of increase is not likely to continue for that length of time. According to the cycle of population increase as indicated by curve in figure , the next period will be of a lower percentage increase than the one just recorded. This is only an assumption tho, and cannot be taken as a definite factor.

However, by considering the many factors which tend to increase or retard the growth of the city in the near future, a factor of 50% increase for each ten year period has been assumed and the population for 1940 estimated at approximately 170,000. This is equal to an increase of 118% for the 20 year period.

With the increase in population there will a corresponding increase in the number of grocery stores, and so forth. A certain percentage of this increase will trade more or less with the market house, however, due to the cheaper prices and other economic factors. Considering the weight of the other factors as well as the lower prices of the market house an assumption is made that about 15% of this increased business will go to the market house. The refrigerating capacity should vary directly as the volume of goods handled, therefore the plant should be increased by 15% in order to take care of the load which might be imposed upon it in 1940.

Maximum possible load as computed for 1940:

$$433,750 \pm ( .15 \times 433,750 ) = 498,800\#.$$

## SIZE OF INSTALLED PLANT

Maximum monthly load as computed above: 498,800 Lbs. of ice.

One pound of ice takes up 144 B. T. U.s in melting.

$$\text{Monthly load: } 498,800 \times 144 = 71,827,200 \text{ B. T. U.s}$$

Daily load: 2,390,900 B. T. U.

One ton of refrigeration: 188,000 B. T. U. removed per 24 hrs.

Theoretical tonnage, 100% volumetric efficiency: 8.3 tons.

Theoretical tonnage, 80% volumetric efficiency: 10.4 tons.

Assumed radiation losses: .5 ton.

Total theoretical load: 10.9 tons.

Size of machine required: 15 ton.

#### MODEL COMPUTATIONS FOR RESULTS IN FOLLOWING PAGES.

Maximum demand for month in 1940:  $498,800/180,200 = 2.76$  of January ice.

Load in B. T. U. per hour: Maximum monthly load times 144 divided by 30 times 24.

Capacity of designed box: Present box capacity enlarged by approximately 25%.

Arrangement of boxes as shown in Fig. "7": Arrangement for convenience of owner and economy of installation.

Coil arrangement: According to nature of contents of box and design of the same.

Total square feet of expansion piping: Hourly load in B. T. U. divided by "K" times  $(T_1 - T_2)$ . "K" = 5.  $(T_1 - T_2) = 13$ . Factor of safety of 2 is taken in this formula due to the fact that 5 instead of 10 was taken as the value of "K".

Total length of piping: Surface of expansion piping in square feet times 2.0. ( Using 1 1/2 inch pipe ).

Cost of expansion piping: Estimated according to style, design, and size of room. The "Frick" Company advises 30 cents per foot.

Cost of installation for stall: Sum of estimated costs of different items as innumeraed above.

Cost per month based on charge of 2.5 cents per 1,000 B. T. U. of refrigeration.

Maximum possible cost per month per stall: Cost when running at full load in 1940, or load equivalent to this.

## STALL 1-R.

L. Lippner.

Meats and Fish.

January ice consumption: ----- 29,000 Lbs.

Maximum probable load: ----- 80,000 "

Maximum load in B. T. U. ----- 16,000 per hour.

Design of boxes:

1 storage box: 8' x 6' x 12'.

1 fish counter: 3' x 3' x 18'.

Box arrangement:

Storage box with metal partition between meat and fish compartments. Two outside doors.

Coil arrangement:

Meat storage box: On side walls.

Fish storage box: In form of shelves.

Fish counter: On side walls and bottom.

Total length of expansion piping: 492 feet.

Approximate number of return bends: 48.

Total cost of installed coils:

|                     |                 |
|---------------------|-----------------|
| Pipe: -----         | \$147.00        |
| Return bends: ----- | 144.00          |
| Total cost: -----   | <u>\$291.00</u> |

Monthly refrigeration charges at present load: \$104.00

Maximum monthly charges at rated full load: \$288.00

## STALL 2-R.

Palace Fish Market.

Fish.

January ice consumption: ----- 6,000 Lbs.

Maximum probable load: -----17,000 "

Maximum load in B. T. U. ----- 3,480 per hour.

Design of boxes:

1 storage box: 4' x 4' x 6'.

1 fish counter: 3' x 3' x 18'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Storage box: On side walls and bottom.

Fish counter: On side walls and bottom.

Total length of expansion piping: 107 feet.

Approximate number of return bends: 14.

Total cost of installed coils:

|                     |                |
|---------------------|----------------|
| Pipe: -----         | \$32.10        |
| Return bends: ----- | 42.00          |
| Total cost: -----   | <u>\$74.00</u> |

Monthly refrigeration charges at present load: \$22.70

Maximum monthly charges at rated full load: \$62.60

## STALL 3-R.

G. J. Renegar.

Meats.

January ice consumption: ----- 14,300 Lbs.

Maximum probable load: ----- 39,500 "

Maximum load in B. T. U. ----- 6,120 per hour.

Design of boxes:

1 storage box: 8' x 6' x 8'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Storage box: Around side walls.

Total length of expansion piping: 190 feet.

Approximate number of return bends: 10.

Approximate number of elbows: 20.

Total cost of installed coils:

|                     |                 |
|---------------------|-----------------|
| Pipe: -----         | \$57.00         |
| Return bends: ----- | 30.00           |
| Elbows: -----       | 20.00           |
| Total cost: -----   | <u>\$107.00</u> |

Monthly refrigeration charges at present load: \$39.00

Maximum charges at rated full load: \$110.00

## STALL 4-R.

John Horne.

Groceries and Vegetables.

January ice consumption: ----- 2,100 Lbs.

Maximum probable load: ----- 5,800 "

Maximum load in B. T. U. ----- 900 per hour.

Design of boxes:

1 refrigerator: 5' x 3' x 3'.

Box arrangement:

Small doors in front.

Coil arrangement:

Refrigerator: Arranged in top compartment in spiral form.

Total length of expansion piping: 28 feet.

Approximate number of return bends: None.

Total cost of installation:

|                       |                |
|-----------------------|----------------|
| Pipe: -----           | \$8.40         |
| Labor: Assumed. ----- | 5.00           |
| Total cost: -----     | <u>\$13.40</u> |

Monthly refrigeration charges at present load: \$5.90

Maximum monthly charges at rated full load: \$16.20

## STALL 5-R.

McNutt Floral Company.

Flowers.

January ice consumption: ----- 2,400 Lbs.

Maximum probable load: ----- 6,620 "

Maximum load in B. T. U. ----- 1,300 per hour.

Design of boxes:

1 storage box: 8' x 3' x 7'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Storage box: On back wall.

Total length of expansion piping: 42 feet.

Approximate number of return bends: 6.

Total cost of installed coils:

|                     |                |
|---------------------|----------------|
| Pipe: -----         | \$12.60        |
| Return bends: ----- | 18.00          |
| Total cost: -----   | <u>\$30.60</u> |

Monthly refrigeration charges at present load: \$8.50

Maximum monthly charges at rated full load: \$23.40

## STALL 6-R.

Economy Meat Market.

Meats.

January ice consumption: ----- 4,900 Lbs.

Maximum probable load: ----- 13,500 "

Maximum load in B. T. U. ----- 2,100 per hour.

Design of boxes:

1 storage box: 8' x 5' x 6'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Storage box: Around side walls.

Total length of expansion piping: 65 feet.

Approximate number of return bends: 5.

Approximate number of elbows: 10.

Total cost of installation:

|                     |                |
|---------------------|----------------|
| Pipe: -----         | \$19.50        |
| Return bends: ----- | 15.00          |
| Elbows: -----       | 20.00          |
| Total cost: -----   | <u>\$54.50</u> |

Monthly refrigeration charges at present load: \$13.70

Maximum monthly charges at rated full load: \$37.80

## STALL 7-L.

S. H. Plemons.

Groceries.

January ice consumption: ----- 5,000 Lbs.  
 Maximum probable load: ----- 13,800 "  
 Maximum load in B. T. U. ----- 2,760 per hour.  
 Design of boxes:

1 storage box: 7' x 3' x 6'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Storage box: On walls in back.

Total length of expansion piping: 81 feet.

Approximate number of return bends: 14.

Total cost of installed coils:

|                     |                |
|---------------------|----------------|
| Pipe: -----         | \$24.30        |
| Return bends: ----- | 42.00          |
| Total cost: -----   | <u>\$66.30</u> |

Monthly refrigeration charges at present load: \$17.90

Maximum monthly charges at rated full load: \$49.70

## STALL 9-R.

R. W. Pierce. Turner Grocery Co.

Groceries.

January ice consumption: ----- 3,700 Lbs.

Maximum probable load: ----- 10,200 "

Maximum load in B. T. U. ----- 2,040 per hour.

Design of boxes:

1 refrigerator: 5' x 3' x 5'.

Box arrangement:

Storage compartment divided into two parts.

Coil arrangement:

Refrigerator: In top compartment with circular coils.

Total length of piping: 63 feet.

Approximate number of return bends: None.

Total cost of installed coils:

|                       |                 |
|-----------------------|-----------------|
| Pipe: -----           | \$ 18.90        |
| Labor: Assumed. ----- | 5.00            |
| Total cost: -----     | <u>\$ 23.90</u> |

Monthly charges for refrigeration at present load: \$13.30

Maximum monthly charges at rated full load: \$36.80

## STALL 10-R.

J. W. Schauer.

Fruits and Sandwiches.

January ice consumption: ----- 1,400 Lbs.

Maximum probable load: ----- 3,860 "

Maximum load in B. T. U. ----- 800 per hour.

Design of boxes:

1 refrigerator: 5' x 2' x 4'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Refrigerator: In top compartment with  
circular coils.

Total length of expansion piping: 26 feet.

Approximate number of return bends: None.

Total cost of installed coils:

|                       |                |
|-----------------------|----------------|
| Pipe: -----           | \$7.80         |
| Labor: Assumed. ----- | 5.00           |
| Total cost: -----     | <u>\$12.80</u> |

Monthly refrigeration charges at present load: \$5.30

Maximum monthly charges at rated full load: \$14.40

## STALL 11-R.

Az Saterfield.

Meats.

January ice consumption: ----- 12,500 Lbs.

Maximum probable load: ----- 34,500 "

Maximum load in B. T. U. ----- 6,900 per hour.

Design of boxes:

1 storage box: 8' x 5' x 6'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Storage box: Around side walls.

Total length of expansion piping: 220 feet.

Approximate number of return bends: 14.

Approximate number of elbows: 28.

Total cost of installed coils:

|                     |                 |
|---------------------|-----------------|
| Pipe: -----         | \$66.00         |
| Return bends: ----- | 42.00           |
| Elbows: -----       | 56.00           |
| Total cost: -----   | <u>\$164.00</u> |

Monthly refrigeration charges at present load: \$45.00

Maximum monthly charges at full rated load: \$124.00

## STALL 12-R.

Knight &amp; Kirby. A. L. Dossett.

Meats.

January ice consumption: ----- 20,550 Lbs.

Maximum probable load: ----- 56,700 "

Maximum load in B. T. U. ----- 11,350 per hour.

Design of boxes:

1 storage box: 8' x 5' x 12'.

Box arrangement:

Divided into two equal compartments.

Coil arrangement:

Storage box: On side walls.

Total length of expansion piping: 350 feet.

Approximate number of return bends: 30.

Total cost of installed coils:

|                     |                 |
|---------------------|-----------------|
| Pipe: -----         | \$105.00        |
| Return bends: ----- | 90.00           |
| Total cost: -----   | <u>\$195.00</u> |

Monthly refrigeration charges at present load: \$74.10

Maximum monthly charges at rated full load: \$204.00

## STALL 13-R.

Thompson &amp; McClannahan.

Meats.

January ice consumption: ----- 4,500 Lbs.

Maximum probable load: ----- 12,400 "

Maximum load in B. T. U. ----- 2,480 per hour.

Design of boxes:

1 storage box: 8' x 5' x 6'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Storage box: On side walls.

Total length of expansion piping: 77 feet.

Approximate number of return bends: 5.

Approximate number of elbows: 10.

Total cost of installed coils:

|                     |                |
|---------------------|----------------|
| Pipe: -----         | \$22.10        |
| Return bends: ----- | 15.00          |
| Elbows: -----       | 20.00          |
| Total cost: -----   | <u>\$57.10</u> |

Monthly refrigeration charges at present load: \$16.20

Maximum monthly charges at rated full load: \$44.60

## STALL 14-R.

J. C. Carey.

Meats.

January ice consumption: ----- 3,000 Lbs.

Maximum probable load: ----- 8,280 "

Maximum load in B. T. U. ----- 1,660 per hour.

Design of boxes:

1 storage box: 8' x 5' x 5'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Storage box: On side walls.

Total length of expansion piping: 54 feet.

Approximate number of return bends: 4.

Approximate number of elbows: 8.

Total cost of installed coils:

|                     |                |
|---------------------|----------------|
| Pipe: -----         | \$16.20        |
| Return bends: ----- | 24.00          |
| Elbows: -----       | 16.00          |
| Total cost: -----   | <u>\$56.20</u> |

Monthly refrigeration charges at present load: \$10.80

Monthly maximum charges at rated full load: \$29.90

## STALL 1-L.

J. A. Bowman.

Fish.

January ice consumption: ----- 18,500 Lbs.

Maximum probable load: ----- 51,000 "

Maximum load in B. T. U. ----- 10,300 per hour.

Design of boxes:

1 storage box: 8' x 6' x 9'.

1 fish counter: 3' x 3' x 18'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Storage box: In form of shelves.

Fish counter: On side walls and bottom.

Total length of expansion piping: 317 feet.

Approximate number of return bends: 30.

Total cost of installed coils:

|                     |                 |
|---------------------|-----------------|
| Pipe: -----         | \$151.00        |
| Return bends: ----- | 90.00           |
| Total cost: -----   | <u>\$241.00</u> |

Monthly refrigeration charges at present load: \$67.20

Maximum monthly charges at rated full load: \$185.80

## STALL 2-L.

G. H. Donehue.

Meats and Sandwiches.

January ice consumption: ----- 7,300 Lbs.

Maximum probable load: ----- 20,100 "

Maximum load in B. T. U. ----- 4,020 per hour.

Design of boxes:

1 storage box: 8' x 5' x 7'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Storage box: On side walls.

Total length of expansion piping: 124 feet.

Approximate number of return bends: 18.

Total cost of installed coils:

|                     |                |
|---------------------|----------------|
| Pipe: -----         | \$37.20        |
| Return bends: ----- | 54.00          |
| Total cost: -----   | <u>\$91.20</u> |

Monthly refrigeration charges at present load: \$26.60

Maximum monthly charges at rated full load: \$72.30

## STALL 3-L.

## Small Fruit Stall.

## Fruits.

January ice consumption: ----- 1,300 Lbs.

Maximum probable load: ----- 3,580 "

Maximum load in B. T. U. ----- 720 per hour.

Design of boxes:

1 refrigerator: 5' x 2' x 3'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Refrigerator: In top compartment.  
Circular coils.

Total length of expansion piping: 24 feet.

Approximate number of return bends: None.

Total cost of installed coils:

|                       |                |
|-----------------------|----------------|
| Pipe: -----           | \$7.20         |
| Labor: Assumed. ----- | 5.00           |
| Total cost: -----     | <u>\$12.20</u> |

Monthly refrigeration charges at present load: \$4.70

Maximum monthly charges at rated full load: \$13.00

## STALL 4-L.

H. O. Lewis.

Drinks, Sandwiches, Etc.

January ice consumption: ----- 2,650 Lbs.

Maximum probable load: ----- 7,200 "

Maximum load in B. T. U. ----- 1,450 per hour.

Design of boxes:

1 storage box: 7' x 3' x 10'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Storage box: On back walls.

Total length of expansion piping: 50 feet.

Approximate number of return bends: 8.

Total cost of installed coils:

|                     |                |
|---------------------|----------------|
| Pipe: -----         | \$15.00        |
| Return bends: ----- | 24.00          |
| Total cost: -----   | <u>\$39.00</u> |

Monthly refrigeration charges at present load: \$9.50

Maximum monthly charges at rated full load: \$26.50

## STALL 5-L.

O. S. Erwin.

Groceries.

January ice consumption: ----- 3,500 Lbs.

Maximum probable load: ----- 9,650 "

Maximum load in B. T. U. ----- 1,930 per hour.

Design of boxes:

1 refrigerator: 5' x 3' x 6'.

Box arrangement:

Storage compartment divided into two  
equal parts by partition.

Coil arrangement:

Refrigerator: In top compartment.  
Circular coils.

Total length of expansion piping: 60 feet.

Approximate number of return bends: None.

Total cost of installed coils:

|                       |                |
|-----------------------|----------------|
| Pipe: -----           | \$18.00        |
| Labor: Assumed. ----- | 5.00           |
| Total cost: -----     | <u>\$23.00</u> |

Monthly refrigeration charges at present load: \$12.60

Maximum monthly charges at rated load: \$34.80

## STALL 6-L.

Davis Bros.

Groceries.

January ice consumption: ----- 3,600 Lbs.

Maximum probable load: ----- 9,950 "

Maximum load in B. T. U. ----- 2,000 per hour.

Design of boxes:

1 refrigerator: 5' x 3' x 5'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Refrigerator: In top compartment.  
Circular coils.

Total length of expansion piping: 62 feet.

Approximate number of return bends: None.

Total cost of installed coils:

|                       |                |
|-----------------------|----------------|
| Pipe: -----           | \$18.50        |
| Labor: Assumed. ----- | 5.00           |
| Total cost: -----     | <u>\$23.50</u> |

Monthly refrigeration charges at present load: \$13.00

Maximum monthly charges at rated full load: \$35.80

## STALL 9-L.

H. B. Jones.

Groceries.

January ice consumption: ----- 2,000 Lbs.

Maximum probable load: ----- 5,660 "

Maximum load in B. T. U. ----- 1,160 per hour.

Design of boxes:

1 refrigerator: 5' x 3' x 5'.

Box arrangement:

Note Fig. "7".

Coil Arrangement:

Refrigerator: In top compartment.  
Circular coils.

Total length of expansion piping: 36 feet.

Approximate number of return bends: 7.

Total cost of installed coils:

|                     |                |
|---------------------|----------------|
| Pipe: -----         | \$10.80        |
| Return bends: ----- | 21.00          |
| Total cost: -----   | <u>\$31.80</u> |

Monthly refrigeration charges at present load: \$7.60

Maximum monthly charges at rated full load: \$30.90

## STALL 10-L.

Market House Creamery.

Dairy Products.

January ice consumption: ----- 6,000 Lbs.

Maximum probable load: ----- 17,000 "

Maximum load in B. T. U. ----- 3,480 per hour.

Design of boxes:

1 storage box: 8' x 4' x 10'.

Box arrangement:

Special interior arrangement.

Coil arrangement:

Storage box: On back walls.

Total length of expansion piping: 107 feet.

Approximate number of return bends: 12.

Total cost of installed coils:

|                     |                |
|---------------------|----------------|
| Pipe: -----         | \$32.10        |
| Return bends: ----- | 36.00          |
| Total cost: -----   | <u>\$68.10</u> |

Monthly refrigeration charges at present load: \$22.70

Maximum monthly charges at rated full load: \$62.60

## STALL 11-L.

B. P. Flennigen.

Groceries and Fruits.

January ice consumption: ----- 700 Lbs.

Maximum probable load: ----- 1,930 "

Maximum load in B. T. U. ----- 400 per hour.

Design of boxes:

1 refrigerator: 4' x 2' x 3'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Refrigerator: In top compartment with  
circular coils.

Total length of expansion piping: 14 feet.

Approximate number of return bends: None.

Total cost of installed coils:

|                       |               |
|-----------------------|---------------|
| Pipe: -----           | \$3.90        |
| Labor: Assumed. ----- | 5.00          |
| Total cost: -----     | <u>\$8.90</u> |

Monthly refrigeration charges at present load: \$2.70

Maximum monthly charges at rated full load: \$7.20

## STALL 12-L.

H. S. Maxey.

Meats.

January ice consumption: ----- 3,100 Lbs.

Maximum probable load: ----- 8,350 "

Maximum load in B. T. U. ----- 1,700 per hour.

Design of boxes:

1 storage box: 8' x 5' x 6'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Storage box: On side walls.

Total length of expansion piping: 56 feet.

Approximate number of return bends: 5.

Total cost of installed coils:

|                          |                |
|--------------------------|----------------|
| Pipe: -----              | \$16.80        |
| Return bends: -----      | 15.00          |
| <b>Total cost: -----</b> | <b>\$31.80</b> |

Monthly refrigeration charges at present load: \$11.00

Maximum monthly charges at rated full load: \$30.40

## STALL 13-L.

Dossett &amp; Hackney.

Meats.

January ice consumption: ----- 7,500 Lbs.

Maximum probable load: ----- 20,500 "

Maximum load in B. T. U. ----- 4,010 per hour.

Design of boxes:

1 storage box: 8' x 6' x 6'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Storage box: On side walls.

Total length of expansion piping: 124 feet.

Approximate number of return bends: 11.

Approximate number of elbows: 22.

Total cost of installed coils:

|                     |                 |
|---------------------|-----------------|
| Pipe: -----         | \$37.20         |
| Return bends: ----- | 33.00           |
| Elbows: -----       | 44.00           |
| Total cost: -----   | <u>\$114.20</u> |

Monthly refrigeration charges at present load: \$27.00

Maximum monthly charges at rated full load: \$ 73.40

## STALL 14-L.

Crouch Stall.

Meats.

January ice consumption: ----- 8,000 Lbs.

Maximum probable load: ----- 22,640 "

Maximum load in B. T. U. ----- 4,640 per hour.

Design of boxes:

1 storage box: 8' x 6' x 8'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Storage box: On side walls.

Total length of expansion piping: 144 feet.

Approximate number of return bends: 6.

Approximate number of elbows: 12.

Total cost of installed coils:

|                     |                |
|---------------------|----------------|
| Pipe: -----         | \$43.20        |
| Return bends: ----- | 18.00          |
| Elbows: -----       | 24.00          |
| Total cost: -----   | <u>\$85.50</u> |

Monthly refrigeration charges at present load: \$30.40

Maximum monthly charges at rated full load: \$123.60

## STALL 15-L.

Haynes &amp; Knight. D. B. Cawood.

Meats.

January ice consumption: ----- 8,000 Lbs.

Maximum probable load: ----- 22,640 "

Maximum load in B. T. U. ----- 4,640 per hour.

Design of boxes:

1 storage box: 8' x 5' x 10'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Storage box: On side walls.

Total length of expansion piping: 144 feet.

Approximate number of return bends: 15

Total cost of installed coils:

|                     |                |
|---------------------|----------------|
| Pipe: -----         | \$43.20        |
| Return bends: ----- | 45.00          |
| Total cost: -----   | <u>\$98.20</u> |

Monthly refrigeration charges at present load: \$30.40

Maximum monthly charges at rated full load: \$123.60

## STALL 16-L.

S. B. Abbott.

Meats.

January ice consumption: ----- 2,500 Lbs.

Maximum probable load: ----- 6,900 "

Maximum load in B. T. U. ----- 1,380 per hour.

Design of boxes:

1 refrigerator: 5' x 3' x 4'.

Box arrangement:

Note Fig. "7".

Coil arrangement:

Refrigerator: In top compartment.  
Circular coils.

Total length of expansion piping: 41 feet.

Approximate number of return bends: None.

Total cost of installed coils:

|                       |                |
|-----------------------|----------------|
| Pipe: -----           | \$12.20        |
| Labor: Assumed. ----- | 5.00           |
| Total cost: -----     | <u>\$17.20</u> |

Monthly refrigeration charges at present load: \$9.00

Maximum monthly charges at rated full load: \$24.90

# DETERMINATION OF MOST ECONOMICAL BACK PRESSURE

Following computations are made for a ten ton installation. Temperature in cooling boxes: 33° F. for all cases.

## POWER COST

Power consumption data: "Mark's Mechanical Engineer's Hand Book".

Efficiency of motor to drive compressor: 80%.

Cost of current: 2 cents per Kw. Hr.

| Suction Temperature. | Theoretical H. P. | Actual H. P. | Input H. P. | Input K. W. | Cost Per Hour. |
|----------------------|-------------------|--------------|-------------|-------------|----------------|
| 0°.                  | 10.72             | 16.08        | 20.10       | 15.00       | \$0.300        |
| 5°.                  | 9.98              | 14.97        | 18.72       | 13.98       | .279           |
| 10°.                 | 9.21              | 13.82        | 17.30       | 12.90       | .258           |
| 15°.                 | 8.55              | 12.82        | 16.10       | 11.98       | .239           |
| 20°.                 | 7.80              | 11.70        | 14.64       | 10.92       | .218           |
| 25°.                 | 7.50              | 11.25        | 14.10       | 10.50       | .210           |

## PIPE COST

Cost of pipe taken at 26 cents per foot for 2" pipe and 19 cents per foot for 1 1/2" pipe.

Temperature in low pressure line equal "T<sub>2</sub>", which is a variable in following computations.

Temperature in cooling boxes: 33° F. for all cases.

Cost of pipe installation taken at 50% of the cost of material.

"K" assumed as 5 for pipe computations.

| Suction Temperature. | "T <sub>1</sub> " - "T <sub>2</sub> " (Degrees) | Pipe Surface. | Linear Ft. 2" | Pipe. 1 1/2" | Total Cost. 2" | Total Cost. 1 1/2" |
|----------------------|-------------------------------------------------|---------------|---------------|--------------|----------------|--------------------|
| 0°.                  | 33.                                             | 727.          | 1164.         | 1454.        | \$454.         | \$373.             |
| 5°.                  | 28.                                             | 858.          | 1371.         | 1716.        | 535.           | 440.               |
| 10°.                 | 23.                                             | 1044.         | 1671.         | 2088.        | 814.           | 536.               |
| 15°.                 | 18.                                             | 1368.         | 2188.         | 2736.        | 1067.          | 701.               |
| 20°.                 | 13.                                             | 1892.         | 3030.         | 3784.        | 1474.          | 970.               |
| 25°.                 | 8.                                              | 3080.         | 4930.         | 6160.        | 2400.          | 1582.              |

Curves in Fig. "6" are plotted from the above results.

Referring to the above computations, note should be made of the fact that for an increase of suction temperature the cost of piping goes up and the cost of operating power comes down. The most economical condition is with a low pressure which will result in the lowest cost for a given length of time. The length of time has been taken as 15 years and the total variable costs estimated for each case. The percentage of saving of one case

over another is then computed and the one showing the greatest percentage of gain in savings is taken to be the most economical condition.

#### VARIABLE COSTS FOR 15 YEARS OF OPERATION

Low pressure temperature: 0° F.

|                               |                    |
|-------------------------------|--------------------|
| Cost of power: -----          | \$39,420.00        |
| Interest on investment: ----- | 335.00             |
| Total cost: -----             | <u>\$39,755.00</u> |

Low pressure temperature: 5° F.

|                               |                    |
|-------------------------------|--------------------|
| Cost of power: -----          | \$36,650.00        |
| Interest on investment: ----- | 396.00             |
| Total cost: -----             | <u>\$37,046.00</u> |

Low pressure temperature: 10° F.

|                               |                    |
|-------------------------------|--------------------|
| Cost of power: -----          | \$33,860.00        |
| Interest on investment: ----- | 481.00             |
| Total cost: -----             | <u>\$34,341.00</u> |

Low pressure temperature: 15° F.

|                               |                    |
|-------------------------------|--------------------|
| Cost of power: -----          | \$31,400.00        |
| Interest on investment: ----- | 630.00             |
| Total cost: -----             | <u>\$32,030.00</u> |

Low pressure temperature: 20° F.

|                               |                    |
|-------------------------------|--------------------|
| Cost of power: -----          | \$28,650.00        |
| Interest on investment: ----- | 1,008.00           |
| Total cost: -----             | <u>\$29,658.00</u> |

Low pressure temperature: 25° F.

|                               |                    |
|-------------------------------|--------------------|
| Cost of power: -----          | \$27,600.00        |
| Interest on investment: ----- | 1,425.00           |
| Total cost: -----             | <u>\$29,025.00</u> |

Curve of the above results is shown on Fig. "6". This curve rises very fast until the point of 20° is reached, and then it flattens out so that the cost for 25° is not much more than it is for 20°. Due to the better operating conditions existing at 20°, or 33# back pressure, this condition is taken as the most desirable and the system so designed. The 1 1/2" pipe also shows a less percent of increase between 20° and 25° than the 2" pipe. Figures in the above table based on 1 1/2" pipe.

## PIPING

From Fig. "7": ----- 291' of exposed expansion piping.  
 From Fig. "7": ----- 390' of low pressure piping.  
 From Fig. "7": ----- 830' of high pressure piping.

Size of expansion piping: ----- 1 1/2".  
 Size of liquid high pressure piping: ----- 1 1/2".  
 Size of low pressure piping: ----- 2 1/2".

Exposed low pressure piping:

|                            |             |
|----------------------------|-------------|
| 291' of 1 1/2" pipe: ----- | 146 sq. ft. |
| 390' of 2 1/2" pipe: ----- | 294 " "     |
| Total: -----               | 440 sq. ft. |

Radiation loss:  $440 \times 5 \times (70 - 20) = 11,000$  B. T. U.

Insulation reduces radiation loss about 85%:

Radiation loss after insulation: ----- 1,700 B. T. U.

Total live load as computed: ----- 99,590 B. T. U.

Total load: ----- 101,300 B. T. U.

Volumetric efficiency: 80%.

Total equivalent load on compressor: ----- 126,700 B. T. U.

Heat removed per pound of ammonia under above conditions:

175# high to 33# low: ----- 471.9 B. T. U.

Ammonia required per minute: ----- 3.60 lbs.

Specific volume of gas at 33# pressure: ----- 5.88 cu. ft.

Ammonia gas per minute: ----- 20.4 cu. ft.

With the maximum demand of only 20.4 cu. ft. of ammonia, the pipes as designed above are all of sufficient size to carry the possible load. Maximum velocities encountered in above designs are in each case less than one fourth of the allowable velocities.

## INSULATION

Hair felt insulation:

|                               |
|-------------------------------|
| 1 layer water proof paper.    |
| 1 layer of 1" hair.           |
| 1 layer water proof paper.    |
| 1 layer of 1" hair.           |
| 1 layer of water proof paper. |
| 1 layer of canvas covering.   |

The cost of the above described insulation quoted by "The Johns Manville Co." at 60 cents per linear foot. This cost price includes installation.

#### CONDENSING WATER.

Discharge pressure: ----- 170#. Temperature: 200° F.

Low pressure: ----- 33#. Temperature: 20° F.

Heat lost between compressor and condenser:

Ammonia entering condenser: (Assumed) ---- 140° F.

Superheat at 200°: ----- 109°.

Superheat at 140°: ----- 49°.

Heat lost:  $.508 \times (109 - 49) = 30.5$  B. T. U. per lb.

Pounds of ammonia per hour at full load: 216.0

Total heat lost: ----- 6,590 B. T. U.

Length of pipe between compressor and condenser:

Assume "T<sub>1</sub>" - "T<sub>2</sub>" (Mean value): ----- 170° F.

Assume "K" as 2.

Heat lost per hour per sq. ft. of pipe surface:

$2 \times (170 - 70) = 200$  B. T. U.

Length of 2" pipe per square foot of surface: 1.6'

Pipe required:  $6,590 / 200 \times 1.6 = 53$  feet of 2" pipe.

Condensing water required:

Highest probable temperature of cooling water: 80°.

Temperature of ammonia:

Outlet to condenser: ----- 82° F.

Inlet to condenser: ----- 140° F.

Temperature of cooling water:

Outlet to condenser: ----- 92° F.

Inlet to condenser: ----- 80° F.

Heat content per pound of ammonia:

Inlet to condenser: ----- 613.8 B. T. U.  
 Outlet to condenser: ----- 86.5 B. T. U.

Heat given up in condenser: 527.3 B. T. U. per lb.

Heat content per pound of water:

Inlet to condenser: ----- 80 B. T. U.  
 Outlet to condenser: ----- 92 B. T. U.

Heat taken up in condenser: 12 B. T. U. per lb.

Total heat given up to condenser by ammonia: 1905 B. T. U.

Weight of water required per minute:  $1905/12 = 159$  lbs.

Gallons of water required: ----- 19.0 per minute.

#### COOLING SYSTEM

Load per hour: 1,140 gallons or 9,500 pounds of water.

Evaporation equal 4%: ----- 380 lbs.

Temperatures of water:

Inlet to cooling basin: ----- 92° F.  
 Outlet from basin: ----- 85° F.

Make up water required to lower 85° water to 80°:

City water temperature: ----- 75°.  
 Make up water required per minute: 9.5 gallons.

Total water required for condenser:

Make up water: ----- 400,000 gallons per month.  
 Evaporation loss: ----- 24,800 gallons per month.  
 Total water used: ----- 424,800 gallons per month.

#### SPRAY TOWER

Location: On roof of building over central plant.

Distance above engine room floor: 60 feet.

Size of water pipe from pump to spraying basin: 1".

Velocity of water through 1" pipe: 8' per sec.

Loss in head due to friction: (Mark) ----- 10'.

Total head on condenser water pump: ----- 70 feet.

Power consumed: Approximate. ----- .4 H. P.

Design of basin:

Pond dimensions: ----- 24' x 24'.

Height of basin walls: ----- 18".

Revolving nozzle in center of basin.

Construction of basin:

Wood construction with sheet iron lining on inside.

#### CENTRAL PLANT ROOM

Size: 15' x 20' with 10' ceiling.

Concrete floor and walls. Plastered ceiling.

Vent through ceiling to roof. Size: 1' x 1'.

Interior arrangement: According to specifications of installing engineer.

#### ELECTRIC WIRING

According to specifications of electrician in charge.

#### WATER CONNECTIONS

According to specifications of plumber in charge.

## COST OF INSTALLATION COMPLETE FOR MARKET HOUSE PROJECT.

Construction of central plant room: Estimated. ----- \$ 500.00

Excavation: ----- \$165.00  
 Concrete work: ----- 285.00  
 Extras: ----- 50.00

Refrigeration Unit: (Bid by Frick Company). ----- 1,095.00

One 6 x 6 enclosed vertical single acting compressor.  
 One 12 pipe high, 20' long, double pipe condenser.  
 One 8" x 8' ammonia receiver.

Freight on refrigeration unit: (Weight: 6630#). ---- 100.00  
 Cost of installing unit: ----- 400.00  
 30' of 7" double ply belting: ----- 60.00  
 Electric and water connections: ----- 75.00  
 Pulleys for speed reduction: ----- 75.00  
 One gas engine, complete: (Fairbanks-Morse Co.) ---- 900.00  
 High pressure liquid pipe: (850 feet) ----- 255.00  
 Expansion pipe: (350 feet). ----- 105.00  
 Low pressure pipe: Return line. (400 feet). ----- 280.00  
 Pipe insulation: (750 feet). ----- 450.00  
 Extra pipe in engine room: (50 feet). ----- 20.00  
 Spray system: ----- 250.00

1" pipe: (750 feet at 20 cents per foot): \$15.00  
 Nozzle: Installed. ----- 6.00  
 Wood for basin: ----- 40.00  
 Sheet metal: ----- 30.00  
 Water pump: ----- 28.00  
 Belting: (20 feet) ----- 8.00  
 Cost of construction: ----- 80.00  
 Incidentals: ----- 43.00

Cost of individual box installations as computed: ---- 1,950.00  
 Expansion valves: (12). ----- 240.00  
 Reducing tees: (15). ----- 75.00  
 Elbows, couplings, etc.: ----- 100.00  
 Installation charges on individual boxes: ----- 500.00  
 Incidentals: ----- 570.00

Total cost of installation: ----- \$8,000.00

## ECONOMY OF OPERATION.

## Fixed charges:

|                                                |         |
|------------------------------------------------|---------|
| Depreciation, at 5% of total investment: ----- | \$30.00 |
| Interest on investment, at 6%: -----           | 40.00   |

## Operating charges:

|                                               |                 |
|-----------------------------------------------|-----------------|
| Fuel for engine: Oil at 12 cents per gal: --- | 90.00           |
| Lubricating oil for engine: -----             | .50             |
| Water per month: Liberal estimate. -----      | 30.00           |
| Wages per month: -----                        | 200.00          |
| Repairs: -----                                | 30.00           |
| Total cost of operation per month: -----      | <u>\$425.00</u> |

Average monthly income: ----- \$740.00

January ice consumption: 180,200#.  
 Average monthly consumption: 212,650#  
 Average monthly income assuming that the  
 consumer pays the same for refrigeration  
 as he does at present for ice at the  
 rate of 35 cents per 100 pounds: \$740.00

Average monthly net profit: ----- \$315.00

## BIBLIOGRAPHY

Actual study was started on this work in the latter part of December, 1922; but no data was taken until the last of January, 1923. At this time the actual monthly ice consumption of the market house was determined. With this consumption as a base, the modifying factors were determined and applied, and the resulting system designed and recommended for installation.

Mention is made of the following authorities:

"Commonwealth of Massachusetts Refrigeration Notes".

"J. H. MacIntire's Principles of Mechanical Refrigeration".

"Power".

"Azbe, in his report on ice costs in A. S. M. E. 1918."

"Mark's Mechanical Engineer's Handbook".

The following men have given valuable aid and suggestions on different parts of the work:

Mr. A. H. Hutchinson, of the "Frick Company".

Mr. Stiles O. Lokey, of "The Triumph Refrigerating Co."

Mr. Hartley, of "The Johns Manville Co."

Mr. Gibbens, of "The Diamond Ice Co."

Stall managers of the market house stalls.

The De La Vergne Machine Co., Henry Vogt Machine Co., Vilter Manufacturing Co., Triumph Ice Co., Frick Co., Delco Light Co., and The Kelvinator Automatic Refrigerator Co. each contributed valuable literature.

# TEST OF DOUBLE ACTING REFRIGERATING PLANT DIAMOND ICE COMPANY

Date: April 19-20, 1923.

Duration: 48 hours.

## COAL ANALYSIS

Moisture: ----- 2.4%  
Volatile Matter: -----30.9%  
Fixed Carbon: ----- 58.7%  
Ash: ----- 8.0%

Heat content: ----- 13,267 B. T. U.

## BOILER CONDITIONS

Boiler pressure: -----143 Lbs. Abs.  
Heat of liquid: ----- 325.9 B. T. U.  
Latent heat: ----- 839.5 B. T. U.  
Total heat of steam: ----- 1016.9 B. T. U.  
Factor of evaporation: ----- 1.048  
Water per lb. of coal as fired: -- 8.8 lbs.  
Water per lb. of combustible: ---- 9.1 "  
Evaporation from and at 212° F. -- 9.56 lbs.  
Water rate: ----- 40471 lbs. per hr.  
Brake horse power developed: ---- 122.8  
Efficiency of boiler: ----- 70.0%

## TEST CONSTANTS

Size of high pressure cylinder: ----- 14" x 21"  
Size of low pressure cylinder: ----- 26" x 21"  
Size of ammonia cylinder: ----- 14" x 21"  
Size of piston rod, high pressure side: -- 2 11/16 in.  
Size of piston rod, low pressure side: --- 2 25/32 in.  
Size of brine pump: ----- 6" x 6" x 12"  
Size of cooling water circulating pump:  
    Cylinder: ----- 12" x 12"  
    Displacement: ---- .7854 Cu. Ft.  
    Slip: ----- 8%  
    Number of strokes per min. -- 32.  
Electric current rate: ----- 3 cents per Kw. Hr.  
Low pressure steam cylinder indicator spring: -- 16#.  
High pressure steam cylinder indicator spring: - 60#.  
Ammonia cylinder indicator spring: ----- 80#.

## TEST DATA AND RESULTS

Duration of test: ----- 48 hours.  
 Average pressures of cards:  
     High pressure steam cylinder, H. E. - 40.0#.  
     High pressure steam cylinder, C. E. - 43.0#.  
     Low pressure steam cylinder, H. E. -- 7.0#.  
     Low pressure steam cylinder, C. E. -- 6.9#.  
     High pressure ammonia cylinder: ----- 56.5#.  
     Low pressure ammonia cylinder: ----- 56.5#.  
 Average pressures:  
     Suction pressure at compressor: ----- 22.0#.  
     Discharge pressure at compressor: ---151.0#.  
     Steam pressure: ----- 128.0#.  
     Receiver pressure: ----- 11.3#.  
 Average vacuum: ----- 22.0".  
 Average temperatures:  
     Ammonia entering compressor: ----- 28.0°.  
     Ammonia leaving compressor: ----- 151.0°.  
     Ammonia entering condenser: ----- 148.5°.  
     Ammonia leaving condenser: ----- 67.5°.  
     Cooling water inlet to condenser: -- 61.0°.  
     Cooling water outlet to condenser: - 73.0°.  
     Temperature of feed water: ----- 181.0°.  
     Temperature of brine: ----- 14.0°.  
     Temperature in calorimeter: ----- 234.0°.  
     Stack temperature: ----- 450.0°.  
 Quality of steam: ----- 96.75%.  
 Revolutions per minute: ----- 77.0  
 Difference, inlet and outlet brine temp. -- 4.8°.  
 Specific heat of brine: ----- .856  
 Weight of brine circulated: ----- 1,232,640 lbs.  
 Brine circulated per hour: ----- 25,680 lbs.  
 Cold produced, B. T. U. per hour: ----- 105,513.6  
 Tons capacity in 24 hours: ----- 45.3  
 Difference, inlet and outlet condensing water: 12°.  
 Weight of cooling water used, in lbs. ----- 4,161,000.  
 Weight of cooling water used per hour: ----- 86,690 lbs.  
 B. T. U. absorbed per hour by cooling water: 1,040,780.  
 Difference, ammonia inlet and outlet to condenser: 81°.  
 Weight of ammonia used per hour: ----- 2,310 lbs.  
 Weight of ammonia used: ----- 108,800 lbs.  
 Weight of dry steam used: ----- 182,688 lbs.  
 Weight of dry steam used per hour: ----- 3,806 lbs.  
 Weight of dry steam per ton of refrigeration: 43.25#.  
 Total indicated ammonia horse power: ----- 71.1  
     Total indicated steam horse power: ----- 81.6  
 Mechanical efficiency: ----- 87.1%.  
 Weight of dry steam per I. H. P. per hour: -- 46.68 lbs.

## RESULTS

Total tons of ice in 48 hours: ----- 90.6  
 Tons of ice per ton of combustible: ----- 8.55  
 Tons of ice per ton of coal as fired: ----- 7.84

## ECONOMICS

## Manufacturing cost per ton:

Coal in yard: (per ton) ----- \$3.50  
 Tons of ice per ton of coal: ----- 7.84  
 Cost of coal per ton of ice: ----- \$0.45  
 Labor per ton of ice: ----- \$0.89  
 Total cost per ton of ice: ----- \$1.34

## Distribution cost per ton of ice:

Labor for distribution, per ton: ----- \$3.00  
 Loss due to bad ice, per ton: ----- \$0.66  
 Total cost of distribution per ton: ----- \$3.66

Incidental expenses per ton: ----- \$1.00

Selling price of ice per ton: ----- \$10.00

Total cost per ton: ----- \$6.00

Net profit per ton of ice: ----- \$4.00

Capacity of plant: ----- 85 tons.

Net profit per day of maximum output: ----- \$340.00

Profit per month of 30 days: ----- \$11,200.00

Actual length of time in operation: ----- 5 months.

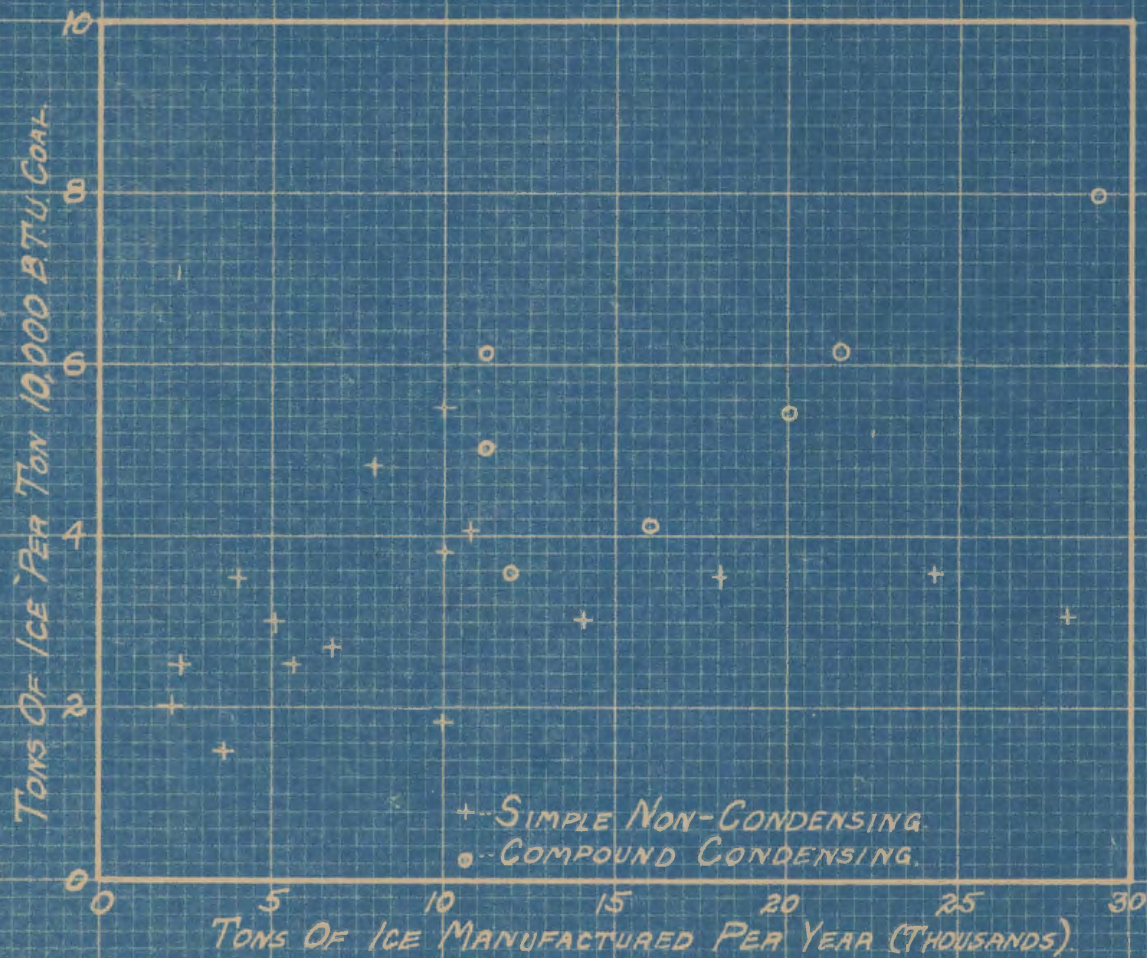
Even break in cost and total sales for other 7 months.

Net profit for 5 months: ----- \$56,000.00

Incidental expenses not allowed: ----- \$6,000.00

Net operating profit for season: ----- \$50,000.00

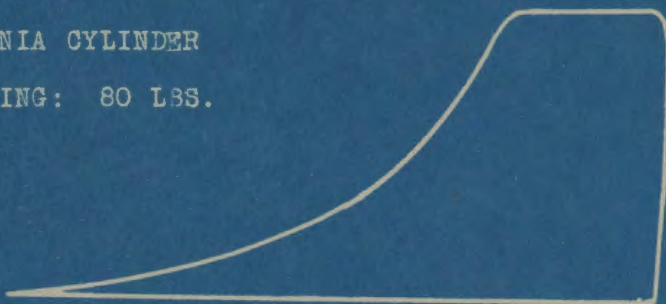
Note: No depreciation or interest on investment has been  
 allowed in the above computations.



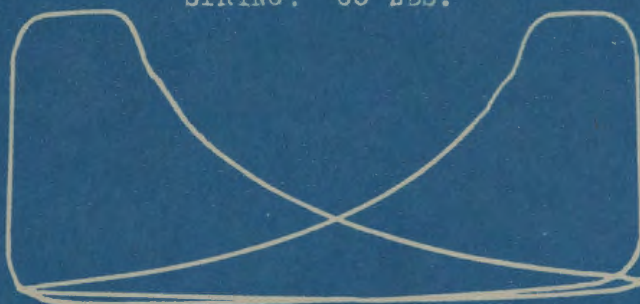
ASME A.S.M.E. 1918.

FIG. 13

TYPICAL CARD  
AMMONIA CYLINDER  
SPRING: 80 LBS.



TYPICAL CARD. HIGH PRESSURE STEAM CYLINDER.  
SPRING: 60 LBS.



TYPICAL CARD. LOW PRESSURE STEAM CYLINDER.  
SPRING: 16 LBS.



APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

Name W. R. Woolrich

Title Assoc. Prof. Mech. Eng.