

Report on Domestic Refrigerating Machines

1923 – 1925

Written by: Alexander Stevenson Jr. (1892-1946)

Assistant to Francis Pratt, Vice President of Engineering
General Electric Co.

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Editorial notes added by Bernard A. Nagengast 2004/2005

A Project by the Historical Committee,

American Society of Heating, Refrigerating and Air-Conditioning Engineers

The original copy of this report was discarded when the Technical Data Library of the General Electric Co. was disbanded. This transcription was based on a badly faded photocopy provided by Ruth Schwartz Cowan, who accessed the original during her research for her book “More Work for Mother” (1983: Basic Books). Due to the poor condition of the photocopy, some lines or words were illegible – in those cases a note was inserted in the transcription: text illegible.

Some appendices included graphs or illustrations that were faded beyond recognition – these were not included. In the case where an illustration was identified with a General Electric photograph number, that information was included should a researcher wish to access the originals located in the General Electric Photo Collection at the Schenectady Museum, Schenectady, New York.

Historical Significance: Alexander Stevenson’s report is the first comprehensive engineering study of household refrigeration, a rapidly developing field in the early 1920’s. The report, written in 1923, with additions in 1924 and 1925 with many appendices, gives the history of General Electric’s involvement in refrigeration, and has information on most of the household refrigeration units in existence at that time. Much of the information can be found nowhere else. Stevenson was assisted in the project by several staff of General Electric’s Ft. Wayne (Indiana) Division including Walter Goll, Works Manager; Clark Orr, master mechanic and lead engineer; Harvey Crane, field service; Robert Steck, chief engineer and James Woods, former Works Manager. (for additional history see: Linkous, Clovis. 1994. General Electric at Ft. Wayne – A 110 Year History. Baltimore: Gateway Press). The Stevenson report provided the justification for General Electric’s entry into the household refrigerator market.

Data Folder No. 1120

Subject DOMESTIC REFRIGERATING MACHINES

Nature Complete Data etc.

By A.R. Stevenson Aug. 17, 1923

Date filed: Aug. 24, 1923.

GENERAL ELECTRIC COMPANY
SCHENECTADY, N.Y.

Return promptly to Data Section Files

DOMESTIC REFRIGERATING MACHINES

Schenectady, N.Y., August 17, 1923

Mr. Gerard Swope,
President,
New York Office,

Dear Mr. Swope:

I forwarded to you on August 14th Mr. Goll's letter to me of August 11th commenting on the report compiled by Mr. A. R. Stevenson, Jr., re above.

After Mr. Stevenson had completed his final draft of the report he spent over a week at Fort Wayne reviewing it in detail with Messrs, Goll, Crane, Orr, Wood and Evans, making such changes in the report at the information brought forth in the conference made desirable.

The report containing the results of a highly skillful, conscientious and unprejudiced investigation made by Mr. Stevenson over a period of a little less than 5 months. In regard to this I want to point out that Mr. Stevenson's investigations were first directed to activities outside of our own Company, and that he did not concentrate his attention on the Fort Wayne situation until he had thoroughly absorbed what had been done elsewhere.

I believe that the report contains practically all information of value currently available which bears upon the business in domestic refrigerating machines.

As recommended in the report, the statements submitted with respect to factory cost, selling expenses, profits and look-up, should be checked and revised by the General Electric Company's Comptroller if we decide to process further in the exploitation of the domestic refrigerating machine business. In this connection I note that

in Table VI, Summary, Report #2, Parts III and IV, Manufacturing and Financial, factory inventory material and apparatus is included as a part of the lockup of the selling company, but in accordance with our established practice it would be included in the factory accounting. In connection with the latter an allowances of 140% on direct labor has been made in the report for factory overhead.

I am sending to you today a copy of the Report comprising three volumes.

The first volume constitutes the Report and the second and third volumes appendices.

Volume I is divided into three parts consisting of Index, Report #1, Summary and Conclusions; Report #2, Historical Introduction – Part 1, Commercial, Part II, Engineering, Parts III and IV, Manufacturing and Financial.

I hope that you will read Report I and as much of Report 2, Parts I to IV, inclusive, as your interest in this subject may lead you to do.

I think that the information given in Volume II and III may be looked upon largely as of reference value.

You will probably recall that I requested Mr. Stevenson to make this report as the outcome of conversations with Mr. Young and later with yourself last March, at which time Consideration was being given to a suggestion made by Mr. F. S. Hunting that we should turn over to Mr. Kettering of the Dayton Research Laboratories of the General Motors Com-

pany a sample of our latest design of OC-2 domestic refrigerating machine made at the Fort Wayne Works. For certain reasons which I stated at the time, I objected to this being done and Mr. Young replied that, considering the probability of the General Electric Company ultimately organizing a subsidiary company for exploiting domestic electrical devices, he deemed it important that we should keep in close touch with the domestic refrigerating machine business. I understood at the time that he had in mind the possibility of such a subsidiary company as that above referred to selling domestic refrigerating machines manufactured by the General Motors Company.

I then made the statement that, in view of such circumstances, it seemed to me that we should encourage the Fort Wayne Works to continue its development as I believed that their designs and manufacturing experiences in this line were superior to those of any one else then in the field.

While it is a fact that the Fort Wayne Works have not been carrying on aggressive developmental work for some time past, yet certain important improvements have been introduced into their designs, and I feel even under these circumstances that Mr. Stevenson's report essentially substantiates the statement which I made at that time.

I am confident that we are today in a stronger position than any one else in this country to handle the engineering and manufacturing activities of a domestic refrigerating machine

business, and the question of the desirability of the General Electric Company exploiting this business is largely a matter of financial, sales and servicing arrangements.

There reads through Mr. Stevenson's report the important fact that all existing practice carries a more than normal hazard of being revolutionized by inventions of a fundamental character. So many active minds throughout the country are being directed to the solution of these problems that it would be perhaps surprising if some such inventions did not materialize. This, of course, introduces a hazard into the business of more than ordinary magnitude.

In considering this subject I think that I should state my conviction that time is decidedly an element in the situation, that the business is a rapidly evolving one, making real strides from the developmental to the commercial stage, and that each year finds a limited number of manufacturers more thoroughly established in the market and gathering into their services the best selling agencies, including the central stations. With relation to this point of view, I also recall that Mr. R. McAllister Lloyd in conversation with me about two months ago expressed the opinion that the art had now advanced to such a state of stabilization as to make it an opportune time to enter into commercial exploitation. While I should not be prepared to accept Mr. Lloyd's opinion in this matter without reserve, yet I do put some weight upon the fact that he has been actively interested in domestic refrigeration for a number of years

past.

It is well understood that heavy financial losses have been incurred in the exploitation of this business, but I suggest that the problem for the General Company to consider is whether the time has not arrived when this business can be made profitable. It seems to me that Mr. Stevenson has treated this phase of the situation in a circumspect and judicial way.

While there are many detailed references in the Report indicating the value of our design and manufacturing experience at Fort Wayne, it does not seem to me necessary that I should make further reference to them in this letter.

I strongly urge that Mr. Stevenson's report, concurred in by our people at Fort Wayne, should receive at this time the serious consideration which I feel it and the subject to which it refers deserve.

If we have in mind providing in the near future as organization particularly adapted for the effective commercial exploitation and financing of the domestic electrical devices, and believe that a domestic refrigerating machine is a logical component of such a line of devices, I would recommend that we should again take up in a comprehensive and affective way development work on domestic refrigerating machines at Fort Wayne, supporting the effort with such assistance as our laboratories and experts located elsewhere could give.

Meanwhile, I will take the responsibility of approving in behalf of the Manufacturing Committee an appropriation of

\$1000 for the purpose of demonstrating so far as possible whether there are merits in the mercury injector suggested by Mr. Hewett, on which preliminary calculations have been made by Mr. Alger, as I believe that more definite information in regard to this has such possible value to the General Company as to justify this small expenditure even though the chance of success is remote.

Very truly yours,
FRANCIS O. PRATT

FCP/ JSH-Jr

CDYoung Dictated by Mr. Pratt

KWRiceJr Signed in his (text illegible)

ARJackson

WGoll

ARStevenson

Publication Bureau

DOMESTIC REFRIGERATION

Report #1
SUMMARY AND CONCLUSIONS

Report #2
GENERAL SURVEY

Report #3
APPENDICES CONTAINING DETAILED INFORMATION

Complied and written by
(signed) A. R. Stevenson, Jr

Concurred in
(signed) Walter Goll
H E Crane
Clark Orr

INDEX

Subject

VOLUME 1

SUMMARY AND CONCLUSIONS

Reasons for Exploitation

- 1- Profits
- 2- Effect on motor business
- 3- String of appliances
- 4- Importance to electrical industry

Type of Machine Desired

- 1- Air cooled
- 2- Low first cost

Available Types of Machines

- 1- Audiffren
- 2- Type OC-2
- 3- Refrigerator box made by the American Balsa Company
- 4- Savage Arms
- 5- Electromagnetic repulsion of mercury
- 6- Automatic Refrigerating Company's compressed air machine

Exploitation

Final Summary

GENERAL SURVEY

Report #2

Historic Introduction

- 1- Audiffren
- 2- Fort Wayne Development

Commercial

Report #2, Part I

- 1- Available types:
 - a. Fort Wayne type OC-2
 - b. Savage Arms Company
 - c. Electromagnetic repulsion of mercury

Subject

Tab

- 2- Probable sales:
 - a- Incomes and Commodity Prices
 - b- Electrical World estimate
 - c- Frigidaire Sales
 - d- Kelvinator Sales
 - e- Washing machine sales
 - f- Vacuum cleaner sales
 - g- Miscellaneous statistics
 - h- Ice statistics
 - i- Inefficiency of ice boxes
 - j- Study of restricted field
 - k- Effect of price
 - m- Caution concerning statistics
- 3- Central station attitude
 - a- Increase in residence lighting load
 - b- Mr. T. I. Jones' estimate of Value of electrical household refrigerator
 - c- Daily load factor
 - d- Annual load factor
- 4- Recommended distribution of sales
 - a- list of cities
 - b- Demand in apartment houses
 - c- Farms
- 5- Commercial requirements
 - a- Most popular size ice box
 - b- Air or water cooled
 - c- Prejudice against refrigerants
 - d- Should machine be mounted as a unit, or in cellar
 - e- Should machine be sold only with special refrigerator box
 - f- Is efficiency or first cost more important
 - g- How much ice should be made
 - h- Importance of quiet operation
 - i- Service
 - j- Best channel for marketing
 - k- Sales arguments
 - m- Personnel
 - n- Organization

<u>Subject</u>	<u>Tab</u>
Engineering	Report #2, Part II.
1- Ice boxes	
2- Rating of ice machines	
3- Comparison of fundamental types	
4- Air or water cooled	
5- Choice of proper refrigerant	
6- Type of pum	
a. Oscillating cylinder	
b. Two stage, herringbone gear	
c. Savage Arms spiral mercury Pump	
d. Electromagnetic repulsion of mercury and injector	
7- Conclusions	
Financial and Manufacturing	Report #2, Parts III and IV
Introduction with discussion of assumptions	
Tables giving general analysis of financial operation	
Schedules giving detailed analysis	
Analysis of price during first three year's exploitation	
<u>APPENDICES</u>	
FACTORY OVERHEAD AND COMPLAINT EXPENDITURES IN CONNECTION WITH PRESENT MANUFACTURE OF AUDIFFREN	Appendix #1
EXPENSES ALREADY INCURRED FOR DEVELOPMENT	`` #2
VALUE OF DOMESTIC REFRIGERATION BUSINESS TO THE CENTRAL STATION	`` #3
STATISTICS ON ICE CONSUMPTION	`` #4

<u>Subject</u>	<u>Tab</u>
REPLIES FROM SUPERINTENDENTS OF WATER WORKS	Appendix #5
ICE BOXES (Includes Climate Maps)	`` #6
DISCUSSION OF THE FACTORS WHICH INFLUENCE THE RATING OF A DOMESTIC REFRIGERATING MACHINE	`` #7
ANALYSIS OF TESTS ON TYPE OC-2 FORM F MACHINE	`` #8
DISCUSSION OF POSSIBLE REDESIGN OF THE FORT WAYNE TYPE OC-2 MACHINE FOR AIR COOLING	`` #9
THEORETICAL ANALYSIS AND COMPARISON OF ABSORPTION MACHINES	`` #10
COMPARISON OF VARIOUS REFRIGERANTS	`` #11
BALSA REFRIGERATOR BOX	`` #12
FORT WAYNE TYPE OC-2 REFRIGERATING MACHINE	`` #13
SAVAGE ARMS REFRIGERATING MACHINE	`` #14
ODIN REFRIGERATING MACHINES	`` #15
WATER VAPOR MACHINE SUGGESTED BY MR. A. R. DODGE	`` #16
SYSTEM OF REFRIGERATION SUGGESTED BY MR. R. W. DAVENPORT OF DETROIT	`` #17
LIST OF PEOPLE INTERVIEWED	`` #18
LIST OF COMPANIES VISITED	`` #19
M. V. ARNOLD'S MACHINE	`` #20
AUDIFFREN SOLD BY JONES MANVILLE COMPANY	`` #21
AUDIFFREN SOLD BY AUDIFFREN COMPANY	`` #22

<u>Subject</u>	<u>Tab</u>
AUTOFRIGO	Appendix #23
BAUER & WAHL	`` #24
BRUNSWICK	`` #25
CHILRITE	`` #26
COLDAY	`` #27
COLDMAKER	`` #28
COMMON SENSE	`` #29
COPELAND	`` #30
CORBLIN COMPRESSOR	`` #31
FEDERATED ENGINEERS DEVELOPMENT CORPORATION	`` #32
FREEZERATOR	`` #33
FRIGIDAIRE	`` #34
FRIGIDOR	`` #35
FRIGOR	`` #36
FRIGORE	`` #37
GLACIFER COMPANY	`` #38
GOETZ ICE MACHINE	`` #39
HAVENSTRITE DEVELOPMENT	`` #40
GEORGE HORANA	`` #41
ISKO COMPANY	`` #42
KARGE LABORATORIES	`` #43
KEITH ELECTRIC REFRIGERATOR	`` #44
KELVINATOR	`` #45
PROFESSOR KEYES' MACHINE	`` #46
KNICKERBOCKER ICE COMPANY	`` #47

<u>Subject</u>	<u>Tab</u>	
KOLD KING	Appendix	48
C. H. LEONARD	''	49
LIPMAN	''	50
MATHES & COMPANY	''	51
McCLELLAN REFRIGERATOR	''	52
MACLAREN FROZEN AIR MACHINE	''	53
MOTORFRIGERATOR	''	54
F. W. NIEBLING	''	55
NORWALK	''	56
OTTO	''	57
RADIANT	''	58
RAPIDE	''	59
REFRIGO	''	60
RUMPLER	''	61
SANITARY (Changed to Frankenburg)	''	62
SERVEL	''	63
C. E. TRIPP'S MACHINE	''	64
UNIVERSAL ICE MACHINE	''	65
UTILITY ICE MACHINE	''	66
FRED W. WOLF COMPANY	''	67
WILLIAMS SIMPLEX REFRIGERATOR	''	68
MR. HUNTING'S REPORT OF REFRIGERATING MACHINE DEVELOPMENT AT FORT WAYNE WORKS	''	69

GENERAL ELECTRIC COMPANY
INTERNAL CORRESPONDENCE

Schenectady, Feb. 21, 1924.

Publication Bureau,
Building #2.

Gentlemen:

I am attaching the following eight appendices
to be included in my large report on "Domestic Refrigeration":

- Appendix #6-A – Refrigerator Suggested by Mr. A. L. Givens.
- Appendix #8-B – An Effort To Explain The Low Volumetric And
Mechanical Efficiency of the OC-2 Form H Machine.
- Appendix #8-C – Tests on the OC-2 Form H Machine #10053, With
1 1/8" Diameter by 3/4" Stroke Oscillating
Cylinders.
- Appendix #15-A – Test of the Odin Domestic Refrigerating Machine
on January 18, 1924, at the Plant of the Automa-
tic Refrigerating Company at Hartford, by Messrs.
Lundgaard, Steck, George and Stevenson.
- Appendix #15-B – Analysis of Tests made by the Consolidated Gas,
Electric Light & Power Company of Baltimore, on
the Odin 15 cu. Ft. Domestic Refrigerating Machine.
- Appendix #15-C – Test Made on the Odin 15 cu. Ft. Box by Putting
Three Electric Light Bulbs Inside of it, on
January 17, 1924, at Hartford, by Mr. Steck and
Mr. Stevenson.
- Appendix #71 -- Mannesmann Tief Kuhlschrank.
- Appendix #72 -- Kleinkalte Maschinen.

Very truly yours,

A.R. Stevenson, Jr.

ENGINEERING GENERAL

ARStevenson, Jr-DW

GENERAL ELECTRIC COMPANY
INTERNAL CORRESPONDENCE

Schenectady, Feb. 21, 1924.

Publication Bureau,
Building #2.

I am attaching the following appendices which
should be included in your report on Domestic Refrigeration:

- APPENDIX #12-A - Information Furnished by Mr. Stuart Otto on
Balsa Box.
- APPENDIX #13-A - Corblin Compressor.
- APPENDIX #14-A - Tests on the Savage Arms Machine.
- APPENDIX #15-A - Addition – Thermometer Corrections.
- APPENDIX #15-D - Tests of the Odin Machine #143 Made by Messrs.
Lundgaard and Stevenson on February 4 &5, 1924.
- APPENDIX #44-A - Information Furnished by Mr. Stuart Otto on
Keith Machine.
- APPENDIX #46-A - Information Furnished by Mr. Stuart Otto on
Keyes Machine.
- APPENDIX #57-A - Otto Refrigerating Machine.
- APPENDIX #71-A - Information Furnished by Mr. Stuart Otto on
Mannesmann Machine.
- APPENDIX #73 - Polaris.
- APPENDIX #74 - Haccius & Bischof.

A.R. Stevenson, Jr.

ENGINEERING GENERAL

ARStevenson, Jr-DW

Report #1

SUMMARY AND CONCLUSIONS

REASONS FOR EXPLOITATION

It is recommended that the General Electric Company should undertake the further development of an electrical household refrigerator as an addition to their sting of appliances, and because widespread adoption will increase the revenue of the central stations, thus indirectly benefiting the General Electric Company. But, the General Electric Company should not enter this field in the hopes of immediate profits from the sale of these machines. For some years to come, the development and complaint expenses will probably eat up all the profits.

On page 36 of the July 1923 number of "Ice and Refrigeration" in the "Report of the Activities of the Trade Development Bureau of the National Association of Ice Industries" there is the following statement:

"More than sixty million dollars have been spent by developers of the Household Machine".

This is probably a very inaccurate statement, but one cannot think of even one-third this amount having been spent without being impressed with the necessity for caution in entering this field. It would seem as though enough money and brains had been spent to prove the difficulty of the problem.

Four general questions which must be considered in deciding whether it is advisable for the General Electric Company to undertake the exploitation of an electric household refrigerator are profits, effect on motor business, string of appliances and importance to electrical industry.

#1 Profits

No thoroughly reliable and reasonably inexpensive domestic refrigerating machine has yet been developed by any of the many companies engaged in this enterprise. During the developmental stage, it is easier to lose than to make money. Therefore, the General Electric Company should not undertake this business in the hope of immediate profits.

On the other hand there is a large and growing demand for these machines. This is discussed in part #1 of report No. 2, where it is estimated that all manufacturers together will sell about 40,500 machines this year. It is also estimated that the business will increase to 138,000 machines sold by all manufacturers in 1934.

It is believed that the General Electric Subsidiary Company could not hope to obtain more than a fifth of this total business.

On these assumptions, the G. E. Subsidiary could in 1934 do a gross business of \$7,320,000 sales of domestic refrigeration machines to dealers. (See table #1, page #4, part #1 of Report No. 2.)

In part 3 of Report No. 2, there is the analysis of the operation of a separate selling organization exploiting domestic refrigerating machines. That analysis would

seem to indicate that after a preliminary year devoted to development and the three following years of commercial exploitation, there would be a substantial return on the investment and most of the development could be liquidated. Predictions of this kind are almost purely guess work, but the details are given in Reports III and IV so that the reader can determine for himself whether the guesses are based on conservative assumptions. Of course, in actual practice the figures might be divided differently. It might even be decided to lower the selling price in order to facilitate sales. This might lessen the sales expense, but it would probably mean smaller profits and consequently a longer period might be required to liquidate the development.

The money “locked up” at the end of each year

Is as follows:

	Lockup at end of year	Average Invest- ment During Year	Profit	Profit expressed as percentage of average invest- ment.
Year of prelimin- ary development	\$126,047*	\$107,297		
First year's exploitation	228,272x	y 177,159	-\$13,125	-7.4 %
Second year's exploitation	406,172x	317,172	20,850	6.6 %
Third year's Exploitation	<u>631,722x</u>	<u>518,897</u>	<u>114,850</u>	<u>22.3 %</u>
AVERAGE		1,120,525 280,131	122,575 30,644	10.8 %

Foot-note*: This figure includes \$88,647 already spent on the development of the water cooled type OC-2 machine. At some
(Cont'd on next page)

Of course, this is all imaginary, but the schedules of operation are given in detail in part III of Report No. 2. By referring to them, it is possible to form an opinion as to how conservative the estimate is.

These figures should be submitted to the Comptroller's Department for revision before they are accepted as final. We are not accountants and we do not have the accurate information concerning probable allocations of General Electric Company corporate expenses, etc.

It is felt that the operation of such a company will depend largely on the ability of the manager and his associates. If it is contemplated having such a company run by one of the G. E. department heads in his spare time, it is felt that it may not succeed. Some one big man must devote his whole time to the job and be held entirely responsible for the success or failure of the domestic refrigeration business.

2. Effect on Motor Business

Mr. F. M. Kimball feels that \$250,000. worth of small motor business with refrigerating manufacturers will be

Foot-note* Cont'd: later time, this water cooled development might be of use in entering the field of refrigeration for ice cream stores, butcher shops, restaurants, etc., where there is quite a demand for machine with capacities from 250 to 400 lbs. of ice per twenty-four hours.

Foot-note (x): These figures include money tied up in material, goods in transit and warehouse, accounts receivable, and unliquidated development.

Foot-note (y) Includes the accumulated loss.

seriously prejudiced if the General Electric Company enters the field of domestic refrigeration.

But, Mr. A. J. Francis feels that the manufacturers of refrigerating machinery would not object if the General Electric Company marketed a domestic refrigerating Machine through some subsidiary company and not under the General Electric name.

After interviewing the officials of many of the companies engaged in the manufacture of domestic refrigerating machines, it is our impression that they would be inclined not to object to a strong competitor who would help educate public opinion to the idea of mechanical refrigeration.

There is also a possibility that in entering the domestic refrigerating field the General Electric Company might secure patents. The motor business might possibly be assisted by offering to license other companies on the condition that they purchase General Electric motors.

If the General Electric Company should develop and put on the market a domestic refrigerating machine of such superior quality as to create a prestige in this field , other manufacturers might want to use G. E. motors in order to partly share this prestige.

At present, the General Electric Company is not getting its proper share of the motor business of the manufacturers of domestic refrigerating machines.

Our recommendations would be that this question of motor business should not be allowed to stand in the

way, if for other reasons it should seem advisable to enter the domestic refrigerating field.

3. String of Appliances

It is increasingly being realized that the “contact with the customer” is the most important feature in merchandising. After sufficient sales effort has been made to establish the “contact with the customer”, it is very important that the salesman have a “string of appliances” to sell. If the customer does not want an electric range, perhaps he will consider the purchase of a washing machine, or perhaps he is interested in an electrical refrigerator.

An electrical household refrigerator is a necessary part of any broad scheme for merchandising electrical household appliances.

One of the best reasons for the General Electric Company’s entering the domestic refrigerating machine business is to complete its string of appliances. If the whole line of General Electric appliances eventually sold under the same trade name, each appliance in the home should be a silent salesman for the rest of the line.

4. Importance to Electrical Industry

The General Electric Company gains by anything which benefits the electrical industry.

There is no doubt but that the electrical household refrigerator is the best household appliance from the

standpoint of revenue to the central stations. It is estimated that in 1934, there will be 560,000 domestic refrigerating machines in operation in the United States. At 2.2 KW-hrs. per day and 5 cents per KW-hr., the annual revenue from each machine is about \$40.00. This makes a revenue of \$22,400,000. to the central stations. Probably the total central station income in 1935 will be \$1,500,000,000. This would indicate that the domestic refrigeration machines might form about 1½ % of the total revenue.

If the revenue from residence lighting, etc., is 16% of the total, then the domestic refrigeration machine might form about 10% of the residence revenue.

For further details see part 1 of Report #2, page 23.

TYPE OF MACHINES DESIRED

In report #2, the proper design of a domestic refrigerating machine is discussed in detail as regards commercial requirements and engineering possibilities. Let it suffice to say here that:

1. The ideal refrigerating machine should be air cooled. It should also be mentioned that the electric power bill of the air cooled machine would be about \$1.30 more in six months than the water cooled machine, but that approximately 86 cents worth of water would be saved. (See appendix #7, page #5).

Since the General Electric Company is entering this field for the benefit of the central station, it would seem wise to exploit a machine in which the total revenue would accrue to the central station rather than partly to the water works.

This question of air cooling versus water cooling is discussed in detail on page #33 of part #1 of Report #2.

2. Since at present prices the interest and depreciation charges are greater than the cost of power, it seems evident that it is more important to obtain a low first cost than high efficiency.

AVAILABLE TYPES OF MACHINES

1. The General Electric Company is at present Building the most reliable small ice machine at present on the market. Some of the Audiffren machines have lasted ten years without ever being opened for repairs. There are very few pieces of machinery that can compare with such a record. On the other hand, it seems impossible to build a machine of the Audiffren design which could be sold with a refrigerator box for much less than \$1000.

Due to the high price and consequent small production, the overhead on these Audiffren machines is so high that the business is no longer profitable to the General Electric Company. For details, see appendix #1, page #1.

If the General Electric Company decides to exploit a domestic refrigerating machine the additional production would help absorb the overhead and thus insure lower costs on both the domestic and the Audiffren machine that would otherwise be possible. If we are to continue the manufacture of the Audiffren machine we should make a new contract with the Audiffren Company which would permit us to do this work at a profit.

The machine now being developed by the Savage Arms Company of Utica, N.Y., may prove successful and a serious competitor of both the Audiffren and the OC domestic machines to be discussed in the following section. This possibility might well be borne in mind in considering a new contract with the Audiffren Company.

2. The Fort Wayne OC 2 (domestic water cooled) machine has in it the essential features which have been so well proven out in the Audiffren design, such as the eccentrics, the oscillating cylinders, the valves and the system of lubrication. We believe that these elements combine to make the most reliable water cooled machine available for production.

In addition the OC 2 is simpler and less expensive to manufacture than the Audiffren design. However, it is water cooled and the commercial demand is for air cooling. It is believed by those most familiar with the past history of this development that the type OC 2 machine can easily be redesigned for air cooling and if placed on the market in the near future would be the best machine available. It is therefore recommended that work start immediately upon the task of modifying this OC 2 machine to permit of air cooling and be prosecuted vigorously. The following program is recommended:

1. That tests be undertaken on the OC 2 machine modified for air cooling and that when sufficient data have been secured.
2. The drawings and patterns be made for an air cooled design.
3. Six models be made and placed in test not only in the shop but also in the homes of those concerned with this work at Fort Wayne.

We have no doubt that the OC 2 machine can be modified for successful operation as an air cooled device,

but we feel very positive that this design should be very thoroughly worked out and proven before a commercial program is undertaken. (We feel that the domestic refrigerating machine business is in its developmental stage and that in all probability some decided and radical improvement may be made in this field which might supersede all present types.) The Savage Arms development already mentioned is an example of the possibilities along this line. Any scheme for exploitation therefore must include in its budget a very liberal development account or it is doomed to failure.

3. It is recommended that refrigerator boxes be purchased from the American Balsa Company. Their box is far superior to any other which can be obtained for the same price. (See Appendix #12).

4. The Savage Arms Company is about to put on the market a domestic refrigerating machine which employs a very novel type of mercury pump. We believe this pump may have great possibilities, but the Savage Arms machine is still a laboratory model and would have to be completely redesigned in order to make a good production machine. (This machine is described in detail in Appendix #14)

We recommend that every effort be made to secure for

test a model of the Savage arms development and pending these tests an option be taken for a license to manufacture under their patents.

5. There is an expired patent #757,393 which covers a refrigerating machine in which the refrigerant is compressed by means of mercury injection. The mercury is pumped by electro-magnetic repulsion.

Recently, Mr. J. R. Hewett has suggested a similar scheme.

Mr. Alger of the Induction Motor Department has calculated a possible efficiency of about 30 percent for a motor through which the mercury could be pumped by magnetic repulsion.

The overall efficiency of the Fort Wayne type OC-2 motor and compressor is about 14½ %.

Therefore, if an injector could be built with an efficiency of approximately 50% (which seems unlikely) #, there is a slight chance of equaling the overall efficiency of our present machine.

It should be possible to build such a machine cheaply, and it would have a great advantage in having no moving parts. This would eliminate the problems of noise and lubrication.

Foot-note (#): When a steam injector is used for feeding water into a boiler, the thermal efficiency is nearly 100% because the heat content of the steam is returned to the boiler. But, when a steam injector is used for pumping water, the latent heat of condensation of the steam is wasted in uselessly warming up the water and the efficiency is from one to two percent. We have been unable up to date to find any data on a mercury injector where the question of latent heat of condensation would not enter.

Of course, the chance of success is slight. Even if success is possible, considerable research and development will be required before it is attained.

We would recommend that this investigator be pushed far enough to determine what the possibilities are.

6. The Automatic Refrigerating Company of Hartford have gotten out a domestic refrigerating machine, the "Odin", which uses air for the refrigerant. (See appendix #15). This machine is interesting, but we are afraid it is inherently expensive and inefficient.

We would recommend that one of these be purchased for investigation and test.

7. Mr. R. W. Davenport of Detroit has suggested a system of refrigeration which is described in appendix #17. This is chiefly interesting because the Detroit Edison Company thinks so highly of it. They say that Mr. Charles M. Schwab, Mr. Carrier of the Air Conditioning Company, and the National Association of Ice Industries, are all much interested in this system. Mr. Davenport believes his invention is worth one million dollars, but we do not believe it is a necessary part of a domestic refrigerating machine. However, experiments should be conducted along the lines outlined in appendix #17.

8. Professor Keyes of Massachusetts Institute of Technology has developed, and is putting out through the National Automatic Refrigerating Company, an absorption refrigerating machine. (See appendix #46.) The is far superior to any of the other absorption machines on the market. Its disadvantages are:

1. It uses ammonia against which there is a prejudice.
2. It is inefficient
3. It is water cooled

Its advantages are:

- a. Noiseless
- b. Perhaps inexpensive to build.

We would recommend that we purchase one of these for investigation and test.

EXPLOITATION.

Since to complete a “string of appliances” was one of the two reasons for entering this field, this whole program hinges on the formation of one subsidiary company to market all domestic appliances. A program for exploitation is discussed in Report #2.

FINAL SUMMARY

Reports #2 and #3 include a complete discussion of the whole subject together with detailed information.

In case the foregoing recommendations are not acceptable, the data in Reports #2 and #3 are available for a study leading to perhaps revised recommendations.

Date Aug 8, 1923

Signed A. R. Stevenson Jr.

Walter Goll

H E Crane

Clark Orr

Report #2
GENERAL SURVEY

HISTORICAL INTRODUCTION.

1. Audiffren

In 1911, Mr. Griscom purchased certain rights under the patents of the Audiffren Singrun machine, formed the American Audiffren Company, made a contract with the General Electric Company to build these machines, and with the Johns-Manville Company to sell them. A rough description of this Audiffren machine is given in appendix #21, Vol. III.

Due to the high price, no great volume of business has ever been done by the Audiffren Company. The General Electric Company has manufactured to date 2510 Audiffren machines.

During the last six years, 1917-1922, the following machines were manufactured and sold.

Year	No. Sold	No. Manufactured
1917	309	302
1918	417	432
1919	273	284
1920	406	362
1921	64	150
1922	167	105
Average	275	275

This year's output will probably be in the neighborhood of 275.

The overhead resulting from this small production is very high. (See appendix #1, Vol. II)

The Fort Wayne factory feels that the Audiffren business is not profitable unless the production of refrigerating machines can be increased.

It was felt that the production of refrigerating machines could probably be increased by marketing a domestic refrigerating machine, because there is quite a large and increasing demand for artificial refrigeration in the home.

Unfortunately, the cost of the Audiffren cannot be decreased by making it smaller. The Audiffren Company estimate that their smallest size ice machine, complete with a ten or twelve cubic foot ice-box, could not be sold for less than about \$900.00 . (For details, see appendix #22, Vol. III.) It would be difficult to do a large volume of business with such a high priced machine.

2. Fort Wayne Development

Realizing that the Audiffren machine is inherently too expensive, the General Electric engineers in charge of its manufacture decided, about 1917, to attempt the design of a less expensive domestic refrigerating machine.

After several preliminary trials, the type OC-2 machine was developed. A brief description of this machine is given in appendix #15, Vol. II. Mr. Hunting's report of January 31st, 1922, gave such a complete description of the type OC-2 machine that it seemed unwise to cover the same ground again.

During the last few years, most of the defects of the type OC-2 machine have been overcome one at a time.

At present, the type OC-2 machine is probably the best water cooled domestic refrigerating machine available.

About thirty of these machines have been built and about twenty-two machines are in service. At the end of 1922, these on consignment were valued at \$6,598.95.

We believe the type OC-2 machine can be resigned for air cooling without much difficulty. In the commercial and financial discussion which follow in parts 1 and 3 of this report, it is indicated that the type OC-2 machine could be sold complete with a refrigerator box having 7 cubic feet food storage capacity for a price of \$593.00. This price includes freight from Fort Wayne to New York and complete installation in the customer's home.

This price compares very favorably with that of the Frigidaire machine put out by the Delco Light Company. The Albany agent of this company told me that their Model B-9, having 9 cubic feet food storage capacity and selling for \$595, is their most popular size machine. This price of \$595, is f.o.b. Dayton, and does not include freight or installation. Also, the B-9 machine is a water cooled machine, so that the installation charge would probably be \$30, for the plumber, in addition to wiring, etc.

The question arose as to whether the General Electric Company should exploit this type OC-2 machine.

About March 20, 1923, an investigation of the whole field of domestic refrigerating was undertaken at the request of Mr. F. G. Pratt.

The subject naturally falls under four main heads: -

I Commercial.

II Engineering.

III & IV Financial and Manufacturing.

The commercial, engineering, financial, and manufacturing aspects are so closely interwoven that it has been impossible to draw definite lines of demarcation between them. It was recommended in Report No. 1 that the domestic refrigerating business should be handled as part of a large Domestic Appliance Company. The organization of this larger company is beyond the scope of this report. Therefore, the financial and manufacturing questions in part 3 were discussed on the assumption of the formation of a separate sales organization. This makes a clear profit and loss statement.

It was felt, if an analysis of the domestic refrigeration business with a separate sales organization showed reasonable returns on the investment, that it would be reasonable to consider it a profitable department for inclusion in a large domestic appliance corporation.

REPORT #2

PART 1

COMMERCIAL

1. Available Types

The General Electric Company might undertake the exploitation of the following:

a. Fort Wayne type OC-2

Up to date about \$88,547.00 has been spent in the development of this machine, and an additional development of about \$41,165.00 would be required to put it on the market.

The following table shows the items of cost, overhead, profits, discount, etc.

The operation during the second year's exploitation has been taken as typical.

Materials, each -----	\$ 87.13)	Schedule
Labor, each -----	28.28)	"H"
140% Expense -----	<u>39.59</u>)	Part III
Factory cost -----	\$ 155.00	
Allocating of G.E.Co. general		
corporate expenses, 10% -----	15.50)	
Manufacturing profit to cover	)	Table II
Investment in plant facilities,	)	Part III
10% -----	<u>15.50</u>)	
Factory bills machine at -----	\$ 186.00	
General commercial expenses of		
subsidiary company or depart-	)	Table III
mental organization, 10.4% ---	<u>19.30</u>)	Part III
Gross commercial cost, not in-		
cluding development -----	\$ 205.30	
Profit, 10.2% of gross commercial-	20.85)	Table V
	)	Part III
Development, 17.6% of factory		
billing -----	<u>32.75</u>)	Table I
District pays for machine -----	\$ 258.90	

District pays for machine - - - - -	\$ 258.90	
	)	Schedule FF
District pays for refrigerator box - <u>80.00</u>	)	Part III
		\$338.90
District selling expense, 28.7%		
of selling price to central	)	Table IV
station - - - - -	<u>141.35</u>	) Part III
Selling price to central station - - -	\$ 480.25	
	)	Schedule Y
Discount to central station, 15%- - <u>84.75</u>	)	Part III
Total selling to customer- - - - -	\$ 565.00	

The various percentages used in making up the above price are explained in detail in Report No. 2, Part III, "Financial".

b. In report #1 it was recommended that a Savage Arms machine be purchased for rest and that an option be obtained on a license for its manufacture. If these tests should be successful and if a satisfactory license agreement could be obtained, it is possible that the manufacture of this machine might be undertaken.

c. There is also a faint possibility that the experiments being carried on in the Research Laboratory on an injector pump run by electromagnetic repulsion of mercury may ultimately lead to a simpler and more inexpensive contrivance than the above.

The general commercial situation will be reviewed from the standpoint of the exploitation of the Fort Wayne type OC-2 machine because it is the machine which we believe offers the most immediate promise of success.

2. Probable Number of Sales

The General Electric Company would not want to sell more than one hundred machines the first year and one thousand the second. If everything went well the first two years, the sales would thereafter be pushed as hard as possible.

- a. We estimate the following sales.

TABLE #1

Year	Number Of Machines	Selling Price Complete	Gross Sales to Ultimate Customer	Selling Price of Machine Alone to Dealer	G.E. Gross Sales
1 st (1924)	100	\$ 592.97	\$59,297.00	\$ 421.21	\$ 42,000.00
2 nd (1925)	1,000	565.00	565,000.00	400.00	400,000.00
3 rd (1926)	3,000	540.00	1,620,000.00	194.00	1,150,000.00
4 th (1927)	6,000	520.00	3,120,000.00	370.00	2,210,000.00
5 th (1928)	9,600	495.00	4,750,000.00	352.00	3,380,000.00
6 th (1929)	13,000	470.00	6,110,000.00	334.00	4,350,000.00
7 th (1930)	15,900	445.00	7,100,000.00	316.00	5,050,000.00
9 th (1931)	18,200	420.00	7,650,000.00	300.00	5,420,000.00
9 th (1932)	21,000	400.00	8,400,000.00	284.00	6,000,000.00
10 th (1933)	27,600	375.00	10,300,000.00	267.00	7,320,000.00

This information is shown graphically on curve H-99399.

NOTE:- Since the preparation of this table it was found advisable to spend an additional year in development before starting exploitation. This would make the dates one year later.

(see diagram)

The preceding estimate was arrived at from a study of incomes, ice statistics and comparison with other commodities, as follows.

1. Although the price of this machine is over \$500.00, it is hoped that by the time the General Electric Company is ready to push the sale that the price will have dropped to \$500.00, due to better methods of manufacture.

It is further assumed that any family with an income of \$5000.00 is a prospective purchaser for this \$500.00 device.

Curve H-99366 was prepared showing the number of people having incomes over \$5000.00. It is immediately apparent that the increase of this number has been abnormal during the past ten years because of the change in the value of money. Therefore, a very erroneous result would be obtained by projecting this curve as indicated.

It seemed evident that a curve of increase in number of people having a purchasing power equivalent to a \$5000.00 income in 1923 was needed.

Therefore, curve H-H99396 was drawn showing the variation of the index price for consumers' goods during the last ten years. It is evident that a \$3180.00 income had the same purchasing power in 1914 as a \$5000.00 income today. The desired curve would, therefore, show the number of people

in 1914 with incomes over \$3180.00, and the number of people in 1923 with incomes over \$5000.00.

Curve H-99395 was prepared from the income tax reports to show the number of people each year with incomes over certain amounts.

The following table was prepared by a combination of the data on curves H-99395 and H-99396.

TABLE #2

Year	Commodity Price Consumers Goods Average Throughout Year	Income Equivalent In Purchasing Power to \$5000 in 1923	Numbers of Incomes of This class and over
1914	100%	\$ 3180	340,000
1915	102%	3250	315,000
1916	120%	3830	370,000
1917	165%	5280	400,000
1918	185%	5900	390,000
1919	220%	7000	380,000
1920	230%	7300	390,000
1921	165%	5250	390,000
1922	150%	4800	
1923	157%	5000	

The above table is very interesting because it shows that while the index prices and the value of money have both been fluctuating, the number of people with a

certain purchasing power has been clearly constant, with an average increase of about one percent a year.

These figures are plotted on H-99397.

In order to see how much the market would be increased by a reduction in price, a similar set of figures was prepared for a machine selling for \$350.00 on the 1923 price level.

It was assumed that persons with an income of over \$3500.00 in 1923 would be prospective purchasers of a \$350.00 device.

The following table was prepared from the commodity prices on H-99396 and the income curves on H-99395.

TABLE #3

Year	Price Index	Income Equivalent In Purchasing Power to \$3500 in 1923	Number of Incomes of This Class and Over
1914	100%	\$ 2230	----
1915	102%	2270	----
1916	120%	2680	----
1917	165%	2670	730,000
1918	185%	3670	750,000
1919	220%	4130	690,000
1920	230%	4900	680,000
1921	165%	5100	1,100,000
1922	150%	3340	----
1923	157%	3500	----

These figures are also shown on H-99397.

Examination of the points plotted on H-99397 shows that the period for which data is available is too short to predict the proper slope of the lines.

We have, therefore, assumed that the purchasing power of the country is increasing in proportion to the population.

Year	Population	Reference
1910	91,972,266	The World
1920	105,710,620	Almanac for 1923
1935	122,000,000	Estimate by W. I. King of the National Bureau of Economics Research

There was a 16 percent increase in population in the ten years from 1910 to 1920. According to Mr. King's estimate, there will be a 16 percent increase in the fifteen years between 1920 and 1935.

If the General Electric Company starts to manufacture a machine with a selling price of \$500.00, it is reasonable to suppose that by improved designs and improved methods of quantity production the cost could be reduced so that by 1935 the selling price might be \$350.00.

The average price of complete domestic refrigerating machines is about \$500.00, and we have assumed a gradual reduction to \$350.00 in 1935.

Therefore, the curve for the number of machines to saturate the country is drawn starting with the number of incomes of a purchasing power above the present equivalent of \$5000.00 (in 1923), and ending in 1935 with the number of incomes above the equivalent of \$3500.00 (in 1923).

We have still further increased the saturation limit 25 percent to include families which have two incomes.

The curve based on these assumptions shows a saturation of 500,000 machines in 1924, increasing to 1,150,000 machines in 1934.

Mr. P. L. Miles of the Edison Electric Appliance Company told me that they had found the following relation to hold for the sales of the electric ranges. Given the number of possible purchasers as 100 percent,

	Percentage of Possible Market <u>Reached each Year</u>
First year - - - - -	1.6%
Second year - - - - -	2.4%
Third year - - - - -	3.6%
Fourth year - - - - -	5.4%
Fifth year - - - - -	<u>8.1%</u>
 Total in five years - - - - -	 21.1%

Using the values shown on H-99397 for the possible market, we have applied Mr. Miles' percentages to them in the following table, from 1919 to 1924.

The values from 1924 to 1934 are calculated backward from the number in operation, which we assume will never exceed half the possible market.

We have assumed that the average life of these machines is five years and shown the 7500 machines sold in 1919 as worn out in 1924, etc.

TABLE #4

(See table)

(See diagrams)

The above table was made up simultaneously

with the drawing of curve H-99398, which represents the same data.

The curve for the total number of machines sold each year by all manufacturers looks very conservative, compared to the extravagant estimates that have been made by some enthusiasts. It will be demonstrated later on by some comparison with the sales of other devices that our estimate is about correct.

We have assumed that the General Electric Company cannot hope to get more than 20 percent of the business, and probably will not reach even that figure before 1934.

Curve H-99399 and the tables of probable sales in the earlier part of this section were based on the above statistics and assumptions.

b. The Electrical World prepared a report for Mr. R. Beecher, president of the D'Aroy Advertising Company, St. Louis, Mo., in 1925, entitled, "An Analysis of the Market for and the Marketing of the Domestic Electric Refrigerator." Their figures compare with ours as follows:

	Estimated by Electrical World #	Estimated by A.R. Stevenson, Jr. #
Number sold in 1919	15,000	7,500
“ 1920	30,000	11,000
“ 1921	25,000	17,000
“ 1922	11,000	27,000
Total in United States at end of 1922	81,000	64,280
Saturation	700,000	500,000

c. Mr. D. W. Weed tells us that he has the following information on good authority from the General Motors Company, concerning the sales of the Frigidaire.

Number of machines sold up to the end of 1921 ----- 12,000
 Number sold during 1922 ----- 1,500
 Expect to sell during 1923 ----- 5,000
 Expect to sell during 1924 ----- 23,000

Mr. Weed further mentioned that the General Motors Company felt that the market for domestic refrigerating machines is larger than the automobile market. It seems obvious that this is a mistaken opinion.

d. Mr. Dwelley, the vice-president of the Kelvinator Corporation, told us that they had 15,000 machines

Foot-note (#) : The Electrical World Figures purport to be actual sales.

Our figures are an estimate of what should have been sold under normal exploitation in normal years.

It is interesting that the total comes out so nearly alike. Their figure of \$1,000 looks high to us.

As regards saturation, they do not mention what price machine they are considering, but they based their estimate on \$5000.00 incomes.

out. They are building at the rate of sixty a day. If their production holds up, they will ship 60 times 300, or 18,000 machines this year.

e. Our Fort Wayne Factory have obtained from the American Washing Machine Manufacturers Association the following list showing the total number of washing machines sold in the United States by all manufacturers.

1920	total sales	565,548
1921	“	289,385
1922	“	422,937
1923	(Jan. 1 to May 1)	177,874

It was impossible to obtain data back of 1920 from the same source.

But, Mr. Aenshaw found an advertisement for Compe Switches in the Electrical World for March 18, 1922, which gave the total selling price of washing machines from 1909 to 1920. Of course, this is not a very reliable source of information, but we divided the total sales by an assumed average price of \$150.00 and plotted curve H-99400.

The same report of the Electrical World referred to in section B, states that 2,500,000 washing machines are in operation.

In 1920, after ten years' exploitation, the number sold was about one-fifth of the number in operation.

Compare this with our refrigerator estimate on H-99398 of 138,000 sold, with a total number of 560,000 machines in operation, which is a ratio of four to one. This curve was based on Mr. P. L. Miles' estimate that during the first few years the sales would increase 50 percent each year.

Examination of the washing machine curve shows,

	<u>Number sold</u>	<u>Percent increase Over previous year</u>
1914	20,000	
1915	30,000	50%
1916	45,000	50%
1917	90,000	100%
1918	167,000	86%
1919	320,000	92%
1920	565,548	76%

H-99398 shows 138,000 refrigerating machines after ten years' exploitation being sold at \$375.00.

This compares very logically with the 565,548 washing machines sold in 1920 at \$150.00. The 60 percent difference in price would easily account for quadrupling the probable sales.

f. Our Fort Wayne Factory have also obtained figures on the total number of vacuum cleaners sold by all manufacturers, and Mr. H. J. Mauger of the Edison Electric Appliance Company has furnished the figures for electric ranges and flat-irons.

YEAR	FLATIRONS #	RANGES	VACUUM CLEANERS
1912	650,000	5,000	
1913	825,000	7,500	
1914	900,000	10,000	
1915	1,000,000	13,500	
1916	1,200,000	20,000	
1917	1,300,000	24,000	
1918	1,400,000	7,500	
1919	1,500,000	22,500	175,500
1920	2,000,000	41,000	1,024,167
1921	1,200,000	16,500	588,502
1922	2,100,000	25,500	745,873

Foot-note (#) : In considering the number of articles in use, the above figures would have to be considerably modified as the average life for an electric flatiron, for example, is probably 7 ½ years, and many of the early type ranges have been discarded.

The previously mentioned report by the Electrical World states that there are 3,000,000 vacuum cleaners in operation. The Electrical World estimates that one million will be sold in 1923.

These figures, considered with relative price, would also seem to confirm the opinion that we have not underestimated the probable sales of refrigerating machines.

g. The following miscellaneous statistics are quoted from the Electrical World, page 1285, for June 2, 1923.

	Estimated # Which will be <u>Sold this year</u>	# in <u>Operation</u>
Household electric ironers	-----	1,500,000
Electrical flatirons	4,000,000	6,000,000
Portable lamps	3,000,000	-----
Fans	800,000	-----
Electrical ranges	75,000	-----
Washing machines	600,000	2,500,000
Vacuum cleaners	1,000,000	3,000,000
Refrigerating machines	22,000	81,000

h. Ice Statistics

The Ice and Refrigeration Bluebook shows an annual consumption of ice for commercial purposes in the

whole United States to be 55,385,000 tons. By the term commercial is meant ice sold to families, butchers, stores, etc. The tabulation by states and months is given in appendix #4, Vol. II.

Incidentally, it is interesting to note that more than seventy percent of the total sales for the year are made in the period from May to September. The peak month is July, during which seventeen percent of the annual sales are made.

The average daily tonnage during July is, therefore, 190,000 tons per twenty-four hours.

Suppose that half of this is used in butcher shops and stores where the demand is larger than could be met by a domestic refrigerating machine.

Suppose that one-quarter of this is distributed to poor families who could not possibly afford to buy a domestic refrigerating machine.

This leaves about 47,500 tons per twenty-four hours which might possibly be replaced by domestic refrigerating machines. If each of these machines took the place of 100 lbs. of ice per day, there would be possible sales for 950,000 such machines in the United States.

The assumptions as to the division of this ice are purely guess work, but the fact that the answer is of the same order of magnitude as that obtained from income statistics is slightly interesting.

i. The inefficiency of the average ice box is thoroughly discussed in appendix #6, Vol. II "Ice Boxes."

Dr. John R. Williams, Secretary of the Milk Commissions, Rochester, N.Y., read a paper, "A Study of Refrigeration in the Home and the Efficiency of Household Refrigerators", before the Third National Congress of Refrigeration, in 1913. The following two quotations from this paper are of special interest.

"The waste from ice meltage because of improper insulation of refrigerators in Rochester homes (population of city 230,000) amounts to 60,000 tons yearly, or about \$350,000. At least \$100,000 more is wasted yearly in the present competitive system of delivery."

"A refrigerator is of little value which will not operate with reasonable care and ice consumption at 45 degrees Fahrenheit, during the summer months"

That the ice companies themselves are awakening to the demand for better refrigeration is illustrated by the following quotation from the National Association of Ice Industries.

"There is no doubt about the fact that a great many women have been dissatisfied with the refrigeration they get from the ice they use, and dissatisfied users are not good prospects for the use of ice the year round.

The committee on National Advertising and Publicity and the Trade Development Bureau have conducted very thorough research since last fall into the possibilities of a line of refrigerators constructed along lines which would assure the ultimate in refrigeration with ice. One big need for the development of such a means to the end of service is found in the radically increasing inroad of the mechanical refrigerator for domestic use.

In particular, Mr. H. H. Bosworth, of the Cleveland Office, says that the City Ice and Fuel Company have purchased seven-eighths of the Freezerator Corporation and are planning to sell this make of domestic refrigerator to their customers. It is rumored in Cleveland that they expect to sell 5000 machines this year and 12,000 machines next year in Cleveland alone.

j. Another way of estimating the demand is by studying a restricted field and then projecting these figures for the whole country.

There are supposed to be about 3,500 domestic Refrigerating machines installed in home in Detroit. This is about nine percent of the total number which we estimated had been sold throughout the whole country.

Another way of getting the demand might be by saying that if in Detroit, a city of approximately 1,000,000 inhabitants, 3,500 machines could be sold, perhaps in the whole country with a population of 100,000,000, 350,000 would be sold with the same amount of exploitation. But, Detroit has probably nowhere nearly been saturated with domestic refrigerating machines as yet.

k. Effect of Price

Mr. J. F. Roche, of the Edison Electric Appliance Company, estimated that by means of intense commercial exploitation we could sell during the first year:

\$800.00	Complete with box	200
\$500.00		7,500
\$250.00		20,000

As an example of how the market narrows with increase in price, take automobiles:

<u>Sold in 1922</u>	<u>Price</u>
36,765	Over \$3000.00
412,000	Between \$1000. and \$2999.
1,560,000	Under \$1000

Mr. G. T. Fielding, director of commercial research of our Bridgeport Works, has send me some figures as follows:

Price of Refrigerator	Income Class of Prospective Purchaser	Total No. of Families in this Income Class in 1922	No. of Families in this Class Living in the City
\$500 to \$600	\$10,000 to \$20,000	148,000	111,000
\$100 to \$150	\$3000 to \$6000	1,094,000	937,000

Mr. Fielding feels that no one with an income Less than \$10,000.00 would buy a \$500.00 or \$600.00 electric refrigerator, and for a man whose income is over \$20,000.00 such convenience for the service would not ordinarily arouse

much enthusiasm. We disagree entirely with this opinion.

The rich people of our acquaintance are very much interested in such contrivances.

m. Caution concerning statistics

There are people of considerable importance who feel that it is impossible to make reliable predictions from statistics of this character.

The following quotation is from a letter by Mr. E. B. Seits, Secretary of the American Washing Machine Manufacturers' Association

“I believe that if you are introducing as you suggest an article which has never been offered to the public, that the question of income of prospective purchasers would not enter into the question to any large extent, i.e., if the article was anything less than \$400.00 because if the article was worth the exploiting, the kind of exploitation which it would receive would determine the quantity. After an article becomes less of a specialty, i.e., after hundreds of thousands of even millions of them are in actual use, then the question of income and family budget become a very highly important factor in arriving at saturation”.

“It so happens that I am a director of a company exploiting on the market a domestic refrigerating machine and we have not at any time tried to estimate the number of machines that could sell from the standpoint of the number of people who could afford to pay our price, mainly because we think that for quite a period of years a successful refrigerating machine can be sold in satisfactory quantities and that it will not be until perhaps several millions of them are in American homes before we will have to take into account what saturation point is.”

We are told that in 1910, it was estimated that there were 22,000,000 horses in the United States. Based on this figure, it was further predicted that three million machines would saturate the automobile market. We believe today there are 15,000,000 automobiles in this country. This shows that the automobile market was very much under-estimated.

In the same way, the foregoing estimates of the number of domestic machines which could replace the present demand for ice, might possibly be an under-estimate, because people who do not use ice today might possibly be educated in the future to use refrigerating machines. It is our impression that education might increase the demand in the southern parts of our country where at present the use of ice is not so widespread as in the more northern portions. There is still more room for increase in England where very few families ever use ice in their homes for the preservation of food.

3. Central Station Attitude

a. There are in the United States 24,351,676 homes. Home denotes the abiding place of a family and does not mean an entire dwelling. Of these homes, 8,467,600 are wired and 1,000,000 new home are wired each year. On page 1269 of the June 2, 1923, Electrical World, there is a table showing

that the average residential customer pays an electric light bill of \$27.00 a year. This would mean that the annual revenue of the central stations from domestic customers is about \$225,000,000.00.

At 2.2 KW-hours per day and five cents per KW-hour, the annual bill for an ice machine is about \$40.00. The total revenue from 64,280 would be about \$2,500,000.00.

There is a chart on page 1272 of the June 2, 1923, Electrical World, which shows that the total annual revenue of the central stations in the United States is about \$1,000,000,000.00. The present domestic refrigeration load is only about one-quarter of a percent of this.

We hesitate to estimate the number of homes that will be wired in 1934, because we feel quite sure that the present rate of increase, one million a year, cannot continue unabated. If this rate should be continued, there would be about twenty million homes wired by 1934. This would mean pretty nearly every home in the country.

On the other hand, we believe the total central station revenue will increase about \$1,500,000,000.00 by 1934.

It was estimated that there would be 560,000 electric household refrigerators in operation in 1934. At

\$40.00 per machine, this would mean about \$22,400,000.00 annual revenue which would only be about 1 ½ percent of the total revenue.

The foregoing estimate of \$225,000,000.00 residence revenue compared with \$1,000,000,000.00 total revenue at present shows a proportion of 22 ½ percent. The following table, giving the distribution of the revenue of one central station, shows a proportion of 16 percent.

If in 1935 the revenue from residences is 16 percent of the total, the electric household refrigerator will probably be about 10 percent of the residence lead.

CENTRAL STATION DEVELOPMENT AT PROVIDENCE, R.I.

April 21, 1923 – Electrical World

Narrogansett Electric Lighting Company – President E.A.

Barrows’ annual report for 1922

SOURCES OF INCOME

Sold other public service corporations - - - - -	25%
Commercial lighting - - - - -	23%
Commercial power - - - - -	21%
Residence lighting - - - - -	16%
Street lighting - - - - -	6 %
Miscellaneous - - - - -	3%
Profit on merchandise - - - - -	2%
Gas - - - - -	2%
Interest on invested capital - - - - -	<u>2%</u>
	100%

b. The electric household refrigerator is an attractive load to the central station because of its good load factor. Mr. T. I Jones, of the Brooklyn Edison Company, estimates that the annual revenue per kilowatt of demand is \$213.33 for the electric household refrigerator: whereas, the electric range has an annual revenue of only \$48.00 per kilowatt of demand.

c. The daily variations in load are really not as advantageous when considered carefully. The refrigerator is most likely to run during the evening because of the constant opening of the doors during the dinner hours. It is not an off-peak device.

d. The annual variation in load is quite advantageous. Most central stations have a smaller load in summer than in the winter. The domestic refrigerator load in summer is likely to be at least double the winter load. This will tend to fill up the valley in the central station load curve.

4. Distribution

a. The Commercial Service Bureau of the Publication Department have made a report, "Sales Possibilities and Publicity Plan for a Domestic Refrigerator (Electric Type)".

This report shows that there is more ice consumed in New York State than in any other. Pennsylvania, Illinois, California, Ohio, and Texas come next in ice consumption.

The best territory for immediate sales is probably in the following states: New York, Massachusetts, New Jersey, Pennsylvania, Ohio, Michigan, Indiana, Illinois, Missouri, and Iowa.

The middle west has, up to the present time, been exploited by domestic refrigerating machine manufacturers to a much greater extent than the east.

We feel that New York City, Philadelphia, and Boston are three very promising fields which have hardly been touched.

We would, therefore, recommend that sales be started in the following order:

1. New York
2. Philadelphia
3. Boston
4. Pittsburgh
5. St. Louis
6. Baltimore and Washington
7. Cincinnati
8. Minneapolis and St. Paul
9. Buffalo
10. Providence

We have purposely left out Chicago, Detroit, and Cleveland, because they are already being intensely Exploited by competitors.

We have also left out the Pacific Coast cities because they are too far away.

For the sake of experience in a hot climate, A few experimental machines should be sold in Dallas, Texas.

b. Demand in Apartment Houses

One great advantage of the large city as a sales area lies in the fact that large individual sales of perhaps one hundred machines may be made to apartment houses.

In quite a few instances, large apartment houses have installed domestic refrigerating machines in all their apartments. It is found that the investment is about the same as for the older installations where one large refrigerating machine is installed in the basement and the brine pumped to each apartment through carefully insulated pipes. There is the further advantage that the power for the individual refrigerating machine will be registered on each customer's meter and will not have to be included in the rents which are already high. It is also probable that a large central refrigerating plant would operate at a very poor efficiency, at times when only a few of the apartments are in use.

The Coldak Company had an order for 374 machines for one apartment, and several smaller orders. The Kelvinator Corporation had several orders for 25 or 30 machines

for apartment houses in Boston. Mr. Grant, the president of the Delco Light Company, said they had sold several lots of machines to apartment houses. But, he said the business with apartments was not so good as it might appear. It took an engineer from the factory to make these large sales, and their credit department has had difficulty in securing prompt payment.

Mr. T. I. Jones, of the Brooklyn Edison Company expressed the opinion that in the future domestic refrigerating machines will be installed in apartments and houses by the builders, in the same way that bath tubs are now. He feels that the commercial cost of selling to contractors would certainly be less than to individuals.

That the architects are waking up to the importance of refrigeration is indicated by a formal request received by the American Engineering Standards Committee from the American Institute of Architects. This communication is too long to quote as a whole, but it starts as follows:

“In connection with the design and equipment of dwellings, particularly multiple dwellings, the architectural profession encounters the problem of domestic refrigerators or “ice boxes”. The problem of selecting this type of equipment is one that concerns also a very large proportion of the lay public wherever the climate requires the chilling of food stuffs for their preservation”.

c. Farms

There is probably quite a demand in rural territory where, at present, it is necessary for each individual to haul his own ice. But, it will be more difficult to sell and service machines in widely scattered territory. Considering that the farm lighting plant business has not been a great financial success, we would recommend that at least in the beginning we avoid scattered sales in country districts. In case this recommendation is overruled, the following statistics may be of interest.

There are 6,500,000 farms in the United States, 500,000 of which are electrified. The central stations furnish 200,000 and the other 300,000 have their own farm lighting plants.

5. Commercial Requirements

Having shown that there is a real demand for electrical household refrigerators and given an idea of the attitude of the central stations, the ice companies, and the architects, and having sketched the territory which should be exploited, it is now necessary to determine definitely the type of machine which should be exploited.

Before deciding to enter the domestic refrigeration field, the following questions should be considered

from a commercial standpoint. They are listed below with the answers in brief. Following the list, each question is taken up more in detail.

- a. What is the most popular size ice box?
7cu. ft. foot storage capacity.
- b. Should the machine be air cooled or water cooled?
It is commercially necessary to have an air cooled machine.
- c. Is there a commercial prejudice against certain refrigerants?
There is a more or less unjustified commercial prejudice against ammonia. For a machine with internal lubrication, sulphur dioxide is probably the best refrigerant, while for a machine without internal lubrication ethyl chloride might be preferable.
- d. Should the machine be mounted as a unit with the refrigerator, or in the cellar?
The demand for these two types of installation is about equally divided. During the first few years, I would recommend that self-contained units only be sold. Later, in order to take full advantage of the market, it will be necessary to supply machines both ways.
- e. Should the machine be sold only with a special refrigerator box, or should it be sold for the use with any box?
The machine should be sold only with a special refrigerator box. Appendix #6, on "Ice Boxes", shows that it is very inefficient and almost impossible to obtain proper temperatures in an ordinary ice box. People will expect better temperatures with a refrigerating machines than they have had in the past with ice.

- f. Is efficiency or first cost the more Important?
First cost is more important than efficiency. This is because at the present time the interest and depreciation charges are larger than the power bill.
- g. How much ice should be made?
12 ½ lbs. per day. It is necessary to make some ice as a sales argument. 12 ½ lbs. is sufficient to freeze two quarts of ice cream.
- h. How important is quiet operation?
Quiet operation is essential because the machine is likely to start up at any time during the night.
- i. What arrangements must be made for servicing and how much will it cost?
There should be a service man within a distance of two or three hours of each machine. Two service men should be capable of handling all the complaints in the largest city. The salaries and expenses of one service man would probably run about \$3000. a year. I believe the dealer should allow 4 percent of the selling price for service.
- j. What is the best channel for marketing these machines and how much will it cost?
They should be marketed as one of a string of appliances handled by a domestic appliance company. The representatives of the domestic appliance company would cooperate with the central stations. At least 40 percent discount would have to be allowed for the selling organization in the field.

For the first few years, neither jobbers nor dealers will be of any assistance.

- k. What sales arguments could be made for a domestic refrigerating machine?
Economy cannot be used as a sales argument, but saving in food, freedom from the ice-man, purity of ice, satisfied users, a desire to be up-to-date, and advertising will help create the demand.
- l. Personnel.
The success of any commercial enterprise depends to a large extent upon the energy and enthusiasm of the men promoting it. It will be necessary to find salesmen and service men, in addition to engineers and factory hands.
- m. Should a separate company be organized?
The refrigerating business should be handled by a separately organized domestic appliance company. The General Electric name cannot be used because this might prejudice other motor business to manufacturers of refrigerating machinery. It would be desirable to have all G. E. appliances bear the same trade name.

The following is a detailed discussion of these questions. Additional information on these same points from an engineering standpoint may be found in Part II of this report, and from a financial standpoint in Part III.

a. Most Popular Size of Box

Most people do not know how many cubic feet food capacity there is in their ice box. The boxes are sold with a rating in pounds of ice rather than cubic feet. We believe the most popular size of ice box purchased by people with the class of incomes under consideration has a rating

of about one hundred pounds of ice. These hundred pound boxes have about 6 cu. Ft. food storage capacity.

The Delco Light Company make the Frigidaire in three sizes: 4.1 cu. Ft., 9 cu. Ft., and 15.5 cu. Ft. We understand that the 9 cu. Ft. food storage capacity box is the best seller. Mr. Grant, the president of the Delco Light Company, feels that a box with 7 cu. Ft. food storage capacity would be the most popular size.

The National Association of Ice Industries has designed an ice box which is being built by the American Balsa Company. This box has 7.08 cu. Ft. food storage capacity. I believe it is the best box, both from the standpoint of construction and low cost, which is on the market, and that if the General Electric Company decides to exploit a domestic refrigerating machine, arrangements should be made to obtain Balsa boxes. This box is described in detail in appendix #12, Vol. II.

To begin with, only the 7 cu. Ft. box should be standardized on. Later, the following sizes might be added:

- 1 – 5 cu. Ft. food storage capacity for
apartment house use.
- 2 – 8 or 9 cu. Ft. food storage capacity
for families in small towns or suburbs
- 3 – 15 cu. Ft. food storage capacity for
moderately large country houses.

4 – 25 cu. Ft. food storage capacity
for very large country houses.

b. Air Cooled Machines versus Water Cooled Machines

Almost all the domestic refrigerating machines on the market today are air cooled. The most prominent of these air cooled machines is the Kelvinator. The Frigidaire is the only prominent water cooled domestic refrigerating machine on the market. Mr. Grant, the president of this Company, told us that they expect to get out an air cooled machine, and, in fact, their present organization would never have put out a water cooled machine if they had not inherited a water cooled machine from the old Frigidaire Company. However, the Delco Light Company expects to continue the exploitation of the water cooled machine, Frigidaire, even after they get out an air cooled one, thus giving customers the choice.

It is shown in appendix #9, “The Redesign of the Type OC-2 machine for Air Cooling”, that with an average temperature of seventy degrees, the 6 months’ power bill for the air cooled machine would be \$1.30 more than the water cooled, but that 86 cents worth of water would be saved. From the standpoint of the electrical industry, it is better to exploit a machine consuming additional current, rather than one dividing its revenue between the central station and the water works.

The water cooled machine has the following disadvantages:

1 – Refrigerators are often installed in a special room, the window of which is often left open in winter. One of the General Electric, type OC-2 machines, installed in Mr. Griswald's house at Erie, froze up and burst the condenser coil. This is a serious disadvantage because it would be very hard to educate the public to the idea that there is a danger of freezing up a refrigerating machine.

2 – A plumber is necessary to install a water cooled machine. This would only cost about \$30.00, but there is a public prejudice against plumbers.

3 – In some places there is sediment in the water which might clog up the machine.

4 – The automatic control of the water is an additional feature which may get out of order.

5 – The average cost of water is about \$1.00 per thousand cubic feet. It can be seen that even in localities where the water costs as high as \$3.00 per thousand cubic feet, the monthly water bill would not be more than about \$3.00. However, in some cases, the water valve has gotten out of adjustment. Water bills are not sent out oftener than every six months. We have heard rumors of installations where a six months' water bill ran as high as \$40.00.

6 – It has been suggested that in some cities water motors are not allowed on the city's lines, and that,

therefore, water cooled refrigerating machine would not be allowed. We wrote to the superintendent of Water Works in forty-one cities in New York State, ten cities in Georgia, and seventeen cities in Texas. Almost all of these, that have replied, state that they are willing to have these machines installed.

7 – It has also been suggested that in hot, dry weather people might be requested to shut off their refrigerating machines. The Superintendent of Water Works above mentioned, all seemed to think that this was a remote possibility. It should be remembered that these men represented the larger cities and that the water supply may not be so reliable in smaller towns and suburbs. Trouble might also be encountered with private water supplies.

In traveling around the country, we have found an almost universal sentiment that a domestic refrigerating machine should be air cooled.

It seemed to be the general impression that the advantages of air cooling would offset the lower efficiency.

Finally, Mr. Hunting, who formerly was a very much in favor of a water cooled machine, has changed his mind and is now of the opinion that air cooling is a commercial necessity.

b. Comparison of Refrigerants

1 – On account of the publicity that has been given to some of the accidents which have occurred in large ice plants, there is a commercial prejudice against ammonia. At present, there is no commercial prejudice against the other refrigerants, although competitors might possibly stir up such a feeling. Appendix #11 should be referred to for a detailed comparison of the various properties of different refrigerants.

It should be mentioned here that there are two machines which use a refrigerant against which there can be no commercial prejudice, namely air. The ODIN built by the Automatic Refrigerating Company of Hartford, Conn., is one of the machines using air as the refrigerant. It is completely described in appendix #15. We believe that there is no doubt that this machine will do what is claimed for it, but we also believe that the construction is inherently very expensive. The MACLAREN FROZEN AIR machine is described in appendix #35. It uses air under 60 lbs. pressure. It can probably be made inexpensively, but we do not believe in its present size that it will do the amount of refrigeration claimed. It is also very noisy. Both of these compressed air machines are inherently very inefficient.

2 – None of the refrigerants are so dangerous as illuminating gas. But, illuminating gas can be a shut off in case of fire.

We wrote the Fire Department of New York City for their rules and regulations with regard to domestic refrigerating machines, but could get nothing definite by way of reply. We have been told by other manufacturers of domestic refrigerating machines that the New York City Fire Department looks at the question of refrigerants from an unexpected angle. They say the fire inspectors do not feel that hermetically sealing the machine is sufficient. They feel that in case of fire, the machine might blow up due to heat, and a fireman might be suffocated by the fumes or burned by an explosion of gas.

d. Complete versus Separate Installation

Mounting the refrigerating machine as a unit with the refrigerator box has the following advantages:

1 – The refrigerating machine and the refrigerator box can be sold as a unit. This tends to secure successful refrigeration because the machine manufacturer can furnish a good box.

2 – The installation charge will be less.

In Cleveland, the charge for mounting a Kelvinator in the basement and piping the refrigerant to the refrigerator on

the floor above is \$22.00.

3 – In apartment houses, a self-contained unit is almost essential because there is no cellar in which it can be mounted.

On the other hand, mounting the machine in the cellar has certain advantages:

1 – Any noise which the machine may make is less likely to cause annoyance.

2 – The cellar is likely to be cooler than the kitchen and an air cooled machine would operate more efficiently in the cooler place.

3 – A water cooled machine would be less likely to freeze up in winter if mounted in the cellar than in a pantry where the window might be open.

4 – Any oil or grease is kept at a distance from the food compartment.

5 – Service men would seldom have to go into the kitchen or pantry because repairs could be made in the cellar.

6 – Sometimes the pantry where the refrigerator is to be mounted is small and in that case, the space saved by mounting the machine in the basement may be important.

After listening to the contradictory opinions

of a great many machine manufacturers, we would estimate that the demand for self-contained units and separate installations in the cellar is about equally divided. In order to take full advantages of the market, it would be necessary to supply machines both ways.

e. Installation in Miscellaneous Boxes

It is apparently a fact that ice boxes sold by department stores are sold for looks rather than insulating qualities. They either waste a great deal of ice or else, the temperature in the food compartment is higher than is necessary for the proper preservation of the food. (See appendix #6, Vol. II., for a discussion of the ice box problem.)

One of the arguments used by the manufacturers of domestic refrigerating machines is that they will preserve the food better than an ice box. Some of them even guarantee certain temperatures in the food compartment. It was obviously impossible to guarantee temperatures in the food compartment, or to guarantee power consumption unless the manufacturer had some control of the design and insulation of the refrigerator box. Therefore, a great many of the companies insisted on furnishing a refrigerator box with their machines.

If the refrigerating machine is to be mounted in or on the box, it is much more convenient to sell a complete unit than to attempt to adapt the machine to any box.

But, a great many people already have ice boxes and there is quite a sales resistance involved in persuading them to scrap the cold box and purchase a new one. Some of the Isko dealers used to make the customer an allowance for the old box, following a similar practice to the automobile dealers. However, one of them told us that they lost money on these second hand boxes because there was no good market for them. Mr. Fisher of the Hurley Washing Machine Company, said they took in a great many second hand washing machines, fixed them up, and resold them. Mr. Fisher felt that a second hand department would be a necessary part of a domestic refrigerating machine business. On the other hand, the Frigidaire Company have never attempted to do a second hand business. We believe we should stay out of the second hand business. If a real demand is created, perhaps independent dealers in second hand refrigerators will grow up.

Some of the manufacturers of domestic refrigerating machines examine the customer's ice box and in nine cases out of ten, agree to install the machine in the old box. The Kelvinator does this. We understand that they to not guarantee food compartment temperatures, but guarantee that the brine tank will be maintained twelve or fifteen degrees colder than ice. They also tell the customer that with a poor box, the power consumption will be increased.

The Frigidaire started in with a policy of insisting on a special box, but are now selling machine for use with almost any box.

In order to sell machines for use with miscellaneous boxes, it is necessary to make expansion coils and brine tanks of all different sizes and shapes. We saw at least a dozen different sizes and shapes of brine tanks on the erecting floor of the Kelvinator Corporation. This interferes with standardization.

Of course, the self-contained units could be sold more like merchandise. It takes a certain amount of field engineering to adapt the machines and ice boxes to each other. Further, the tests on standard ice boxes given in appendix #6, page #5, show that to maintain 40 degrees in these ice boxes it would be necessary to run at very low brine temperatures. This might freeze the food. It is, therefore, almost impossible to obtain proper refrigeration in an ordinary box on a 90 degrees day.

We believe we should start in selling complete units and later, if necessary, take up the question of installations in existing boxes.

If a self-contained unit is sold, another question is involved. Should the manufacturer make his own box, or buy from existing ice box manufacturers? It has been suggested that if the manufacturer builds his own boxes he

will antagonize all the other ice box manufacturers. We do not believe this is serious. The automobile companies have not felt it necessary to buy their bodies from the old carriage builders. The ice box manufacturers have shown so little brains in the design of their ice boxes that with proper engineering talent, the machine manufacturer can probably produce something far superior.

There is one company, however, whose ice boxes should be considered for possible modification and adoption. The box made by American Balsa Company is described in appendix #12, Vol. II. This company is owned by the American International Corporation. We believe that the General Electric Company has very friendly relations with this company, and arrangements might possibly be made to use their boxes.

f. Efficiency versus Cost

It would be unwise, at least at first, to assume that these domestic refrigerating machines would last more than ten years. In fact, we do not know of any except the Audiffren which have been operating more than five years. A ten or twenty percent depreciation charge is larger than the power bill. Therefore, from a sound economic standpoint, first cost is more important than efficiency. We also feel that there will be less sales resistance the lower the price.

A great many of these machines are being sold today on the argument that the power bill is less than the ice

bill, the question of interest and depreciation being slurred over. Apparently a great many people shut their eyes to the fact that the machine will not last forever. But, even so, it would be our opinion that a low first cost is more important than efficiency.

In deciding between efficiency and first cost, it should be pointed out that for the benefit of the electrical industry it is better for the customer to pay a little more to the central station in the form of power bills than to expend the same amount of money for interest and depreciation.

g. Amount of Ice Required

Mr. Roche, of the Edison Electric Appliance Company, told us that when electric ranges were being introduced it was of great sales assistance to be able to point out to the customer red-hot coils. This ocular demonstration of heat was apparently more convincing than merely the touch of a hot plate. Similarly, it will be of great sales assistance if these domestic ice machines made at least a few cubes of ice. Most of the companies now in the business say that their experience leads to the same conclusion.

On the other hand, almost all the people we have interviewed have felt that it was unnecessary to make enough ice to make ice cream.

The Frigidaire 15 cu. Ft. outfit freezes 9 lbs. of ice in eight hours. This is divided into 72 cubes.

This would allow twenty-four cubes for each meal which would make sufficient for drinking water with some left of for butter, salad, etc.

It takes at least 12 ½ lbs. of ice to Freeze two quarts of ice cream.

The Savage Arms machines, which is one of the most unusual and interesting machines about to be placed on the market, makes 40 lbs. of ice in about six hours. But, this ice is used in place of a bring tank to hold the box temperatures while the machine is shut down. Of course, this ice is available for other purposes. If it is removed, it is only necessary to run the machine longer to keep the box cool and freeze some more ice.

In conclusion, it is necessary to make a little ice because it is a sales assistance. It is not absolutely necessary to make more than five to ten pounds. But, there is no harm in making more ice if it can be done without sacrificing other features.

It would seem desirable to have a capacity of about 12 ½ lbs., so that two quarts of ice cream can be frozen if desired. It would also be advisable to have the ice compartments so arranged that when the trays are removed a covered dish containing a dessert can be inserted for freezing.

h. Quiet operation

The importance of quiet operation cannot be overestimated. People do not object especially to a noisy vacuum cleaner or a noisy washing machine because these are run only during the day. But, most of these refrigerating machines start up at almost any time and the slightest noise in the dead of night is very disagreeable. People may get used to this, but there will be a sales resistance until they do. The Savage Arms Company expect to store enough ice during the day so that the machine may be shut down at night.

Of course, arranging the machine so that it will be shut down during the middle of the night will reduce the attractiveness of the load from a control station standpoint, because the machine would never run during the off-peak period.

i. Servicing

It would be unreasonable to assume that any of these machines would run without service. The Audiffren is probably the most fool-proof machine on the market. Some of them have run ten or eleven years without trouble. But, on the average, there are 4 percent complaints. This means that the amount of cost of repairing machines and adjusting complaints is 4 percent of the annual factory cost of

machines shipped. The Kelvinator Corporation claim two service calls per machine per year on their average. The Frigidaire corporation state that two adjustment calls and three other service calls, making a total of five, will be required the first year.

If a refrigerator breaks down, the food will spoil unless its is fixed almost immediately. Therefore, prompt service will be necessary in order to give satisfaction.

The service may be done in two ways. The Kelvinator Corporation makes almost all its repairs in the field. They find that two service men can handle this eight complaints per day which occur in Detroit, where 1500 Kelvinators are installed. This method requires trained mechanics in each locality. The Kelvinator Corporation runs a school for service men and will not give a dealer an agency until one of this employees has been through the school and has a certificate.

Another method is to make a machine like the General Electric, type OC-2, which is completely enclosed in a case. The control could be repaired in the field by a service electrician, but if anything went wrong inside the machine itself, it would be removed and shipped back to the factory for repairs. It would then be necessary either to supply the customer with a spare machine, or else arrange the customer's box for the use of ice during the period of repair.

The objections to this method are:

1 – The extra investment in spare machines.

This might be avoided by using ice.

2 – It takes two or three men to lift the machine in and out. This, together with the trucking and freight charges, is expensive.

In appendix #13, Vol. II, will be found an historical sketch of several of the type OC-2 installations.

If there are many complaints, it would be better to make repairs in the field.

But, if the complaints can be reduced to less than one per machine, per two years, then the system of returning the machine to the factory for repairs would be justified.

At least 4 percent of the selling price should be allowed for service to be going with. This might be reduced later if the machine turned out to be much more reliable than any of those at present on the market.

The question of service is treated more thoroughly in Part III of this report.

j. Merchandising Channels

There are very divergent opinions as to the best method of marketing domestic refrigerating machines. On

one point, however, the opinion is almost unanimous, i.e., that the jobber will serve no useful purpose in the system. (Perhaps later, after the business is thoroughly established, the jobber might be given a chance.)

1 – It might be thought that this business should be done through dealers. The dealer would want not less than 25 percent and probably 40 or 50 percent discount. However, the dealer cannot be relied upon to push a new device, and we should not rely upon him in the early stages although later when the product is thoroughly established, he might be useful.

2 – Some of the central stations would like to handle the sale of these machines in their territory. They have the added incentive of the extra revenue from power sales. However, the public service commissions would not allow them to charge a merchandising loss as an operating cost, and they would need about 40 percent to push this business. The fact that some of them think they only need 25 percent would tend to indicate that they are not familiar with intensive sales campaigns and the expenses involved. It is questionable whether the central stations would have the enthusiasm necessary to really promote sales. It would probably be necessary for the manufacturer to send a representative to each town to properly enthruse the central stations Commercial Department.

and show them how to put on a sales campaign. This method is being followed at present by the Edison Electric Appliance Company.

3 – Another method would be for the manufacturer to have his own representatives in each territory. He would probably have to spend the same 40 percent to do this as would the central stations, but might be able to keep his own representatives up to a high water mark of enthusiasm.

4 – There is also the question as to whether the individual salesman should sell only refrigerating machines, being a thorough expert on that subject, or whether he should handle a “string” of appliances.

The Edison Electric Appliance Company seemed to favor a salesman who sold only electric ranges and was a thorough expert on that subject. They felt that if the salesman handled a “string” of appliances, he would be a “jack of all trades and master of none”.

On the contrary, Mr. Barber, in charge of merchandising for the Western Electric Company, told me that people were coming to realize that a string of appliances are a necessity to good merchandising. It is felt that after having made the sales effort involved in obtaining extremes to a bone, the salesman should be prepared to sell any one of a number of domestic appliances in which he discusses that

the family happens to be interested. It if turns out that the family did not want a refrigerating machine, perhaps an electric range or washing machine might be sold instead. If an expert is necessary, the salesman could call for his assistance in the final stages of the proposition after the contact has been thoroughly established. Also, after selling any one of these contrivances, the way is open for the same salesman to return and sell some other appliance later.

This type of question would probably be decided by whoever was made sales manager of the new company.

5 – Another alternative would be to make arrangements with the Western Electric Company to market the refrigerating machine. If a good, inexpensive, fool-proof machine could be found, I believe they would be very open to such a proposition. Perhaps the Edison Electric Appliance, the Hurley Washing Machine Company, or the Electric Vacuum Cleaner Company would want to consider the commercial exploitation of a household electrical refrigerator.

If any of these companies undertook the commercial exploitation, the General Electric Company would probably have to give them a jobber's commission of 25 percent, but its own commercial overhead could be reduced to about 10 percent.

6 – Still another alternative would be to get the ice companies in each locality to take up the sale of domestic refrigerating machines. The City Ice and Fuel Company

is doing this in Cleveland at present. From our personal experience with ice companies in the sale of large electrical apparatus for their ice plants, we would be inclined to believe that very few of them have the personnel with either the enthusiasm or commercial experience to push such a device. It is also our impression that in most places the ice companies are unpopular, and look on with suspicion by their customers. We would, therefore, hesitate to recommend this method of selling.

The cost of selling would be about the same, no matter which system was adopted. An analysis of this cost will be found in Part III.

k. Sales Arguments

The sales arguments can be classed as follows:

1 - Economy

It has been demonstrated that the power bill for a domestic ice machine with a reasonable rate of say five cents per KW-hour, is about 65 or 70 percent of the cost of ice at 60 cents per hundred-weight. It appendix #3, Vol. II, there is quoted a table from Mr. T. I. Jones' paper showing the comparative cost of operation. At present prices, the interest and depreciation on the cost of the refrigerating machines over-balance the fact that power costs less than ice.

Mr. Jones points out that with current at five cents per KW-hour, and ice at 60 cents per hundred-weight, a 6 cu. Ft. electric machine must be sold complete with a box for \$175.00 to equal the present ice cost. Mr. Jones has included the refrigerator at \$100.00. This leaves \$75.00 as the selling price of the refrigerating machine. This would mean a factory cost of \$28.00. This may ultimately be possible, but will not be attained until they are manufactured on the same scale as the Ford Automobile. No matter how good a device was available, no one would dare go into such elaborate production during the first few years, until after all unforeseen difficulties had come to light. Mr. Jones also figures that a 10 cu. Ft. machine should sell complete with a \$150.00 box for \$269.00. This leaves \$119.00 as the selling price of the machine, or a factory cost of about \$45.00. This is nearer attainment. We have seen one or two machines which it was claimed, could be manufactured for a cost in the neighborhood of \$65.00, although these would have to be investigated much more thoroughly before relying on such a figure.

It is, therefore, evident that there is no real economic saving at the present time to be obtained by putting in a mechanical refrigerator in most places where power costs at least five cents, and ice about 60 cents.

But, in Schenectady, power only costs three cents per KW-hour and ice costs 80 cents per hundred-weight.

Under these conditions, using Mr. Jones' own method of figuring, the 6 cu. Ft. electrical refrigerator is, even at a selling price of \$225.00 for the machine alone, a little bit less expensive than ice. For the 10 cu. Ft. box, the machine itself would have to sell for about \$315.00, which is also possible. However, these figures are based on 10 percent depreciation and this is rather optimistic.

Even under the most favorable assumptions, the saving is so slight that it can hardly be used as an argument.

2 – Saving of Food

Saving of food is perhaps a good argument for a domestic refrigerator. In order to really preserve food, the box should be kept under 45 degrees in the food compartment. This is very rarely the case with ice boxes in hot weather. Personally, I believe that the old superstition that a thunderstorm curdles the cream has arisen because just before a thunderstorm it usually very hot. The old-fashioned refrigerator is not capable of maintaining a low temperature with the room at 80 or 90 degrees, and the cream curdles due to heat. After once warmed up, it takes the box some time to cool off, and perhaps the cream does not sour until after the storm has cooled the atmosphere. However, this sales argument has the flaw that with proper insulation at 45 degree temperature can be maintained with ice.

It is also claimed that the dry cold of a refrigerating machine preserves the food better than the damp cold of a refrigerator. There may be something in this. On the other hand, the ice men claim that the melting ice carries off odors which deposit on the brine tank of a refrigerating machine. However, when the brine tank is defrosted, the melting frost has a tendency to wash the brine tank, although it is true that this washing action is not complete.

3 – Freedom from Ice Men

Another argument is freedom from the ice man. In small families it is sometimes a hardship when one member has to stay at home to let the ice man in. The ice man is quite often late, and considerable time may be wasted in this way. It is also a nuisance having a man, perhaps with muddy boots, carry a dripping piece of ice through the house.

In apartment houses, the ice is sent up on a dumb-waiter and it is necessary for some member of the family to lift it out of the dumb-waiter into the ice box. This is sometimes a physical stain.

But, if many service calls are required for the machine, the service man may cause as much dirt and inconvenience as the ice man.

4 – Purity of Ice

No matter how carefully the ice is made from

pure water in a large ice plant, there is always danger of contamination during its delivery. I remember taking lunch with the owner of a large ice plant and the engineer of another very large plant. They both agreed that although all possible precautions were taken to keep the ice clean, they themselves would hesitate to drink water containing their ice. With the domestic machine, the little cubes of ice, being made in the customer's own home, are not likely to have any dangerous germs if the water used in making the ice is pure.

5 – Delivery

In some country places and suburbs, the ice companies will not deliver and it is quite a nuisance for the customer to haul his own ice. In these cases, a domestic refrigerating machine is almost a necessity.

6 – Demand Through Advertising

In addition to the above, there is the fact that advertising has created a demand for electrical appliances in the house. And, some people will probably buy electrical refrigerators just for the sake of having another electrical appliance in their homes.

7 – Satisfaction

We think it is also the case that in spite of the troubles encountered, most of the users are satisfied and could not be persuaded to go back to ice.

m. Personnel

Mr. P. L. Miles, who handles the sale of electrical ranges for the Edison Electric Appliance Company, said that he would like to have a chance to exploit domestic refrigerating machines. Commercial men might be borrowed from some of our other domestic appliance companies.

Since the Fort Wayne type OC-2 machine is entirely self-contained and would be shipped back to the factory in case anything went wrong on the inside, the field service problem resolves itself into purely a matter of electrical control. It should be very easy to find men capable of handling this part of the problem.

It seems to us that in order to insure success some one man should be made completely responsible for the domestic refrigeration business and given full authority.

n. Organization of Separate Company

Mr. Francis assures us that the General Electric Company could sell one hundred domestic refrigerating machines as an experiment under its own name without hurting its fractional horsepower motor business. However, Mr. Francis feels that if the General Electric Company really goes into this business, it would hurt the motor sales to other refrigerator manufacturers if the business were carried on under the

General Electric name. But, the motor business would not suffer if the General Electric Company was known to hold a controlling interest in some subsidiary manufacturer of domestic refrigerating machines under another name.

Mr. F. M. Kimball seemed to feel that it might prejudice \$250,000.00 worth of small motor business if the General Electric Company got out a domestic refrigerating machine under any name.

It also seems likely that a small organization whose existence depended on making a success of the refrigerating machine might make more strenuous efforts to make it a success than a more generalized department.

The General Electric Company has already established several precedents in the manufacture of domestic appliances under other names in subsidiary companies. The people familiar with the operation of these companies can best decide whether the precedent should be followed in this case also.

Since the completion of a "string of appliances" is the best reason for entering the electrical household refrigerator business, we should feel that the best method of exploitation would be through a subsidiary company which would be organized to exploit all the domestic appliances which are at present being sold by several different subsidiaries.

Report #2

Part II

Engineering

1. Ice boxes: From an engineering standpoint, the average ice box is a very poor design. Too much attention has been paid to appearance and too little to the insulation necessary to obtain good refrigeration temperature and economical ice meltage. Cork insulation is really very cheap. It can easily be demonstrated that an extra investment in cork insulation will pay for itself because lower temperature in the food compartment can be obtained with less ice. In appendix #6, Vol. II, "Ice Boxes", it is calculated that if 1" additional cork insulation is added to an average 100# ice box, the saving in ice will pay 6% interest, 10% depreciation and 18% profit on the additional investment. The same appendix includes considerable more information of the same character.

In order to obtain low enough temperature in the food compartment of the average ice box, it would be necessary to run a refrigerating machine with an unreasonably low brine temperature. This would be impossible with some machines and very inefficient with others. In appendix #7, Vol. II, "Discussion of Factors which influence the rating of a domestic refrigerating machine", it is shown that the addition of 1" of cork to an average 100# ice box will cause a saving on ice equivalent to 6% interest, 10% depreciation and 26% profit on the additional investment. This is not so much due to the reduction in refrigerating effect, but to the higher efficiency of the machine when operating with a higher brine temperature.

It is therefore not recommended that the General Electric Company sell machines for installation in miscellaneous boxes.

The American Balsa Company is making a 100# ice box which is really a good engineering design.

	<u>High</u>	<u>Wide</u>	<u>Deep</u>
Out side Dimensions	50"	35 1/2"	21"
Food Compartment	36 5/8"	16"	15 5/8"
Milk Compartment	11 5/8"	13"	15 5/8"
Ice Compartment	27"	14 1/8"	15 5/8"

*The ice compartment is apparently large enough to accommodate the bring tank of the type OC-2 machine.

Cubical Content in Cu. Ft.

Total inside	-	-	-	-	-	-	10.53
Ice Chamber	-	-	-	-	-	-	3.45
Food and Milk Chambers	-	-	-	-	-	-	7.08

A 96 hour test was run on this box with a 70 degree Fahrenheit room Temperature.

The average temperature in the food compartment was 44 degrees Fahrenheit and the average ice meltage was .802 lbs. per hour.

In order to appreciate the excellence of the above performance, it is necessary to refer to the tests on average boxes shown in appendix #6, Vol. II.

The box is constructed as follows:

Two inches of balsa wood dovetailed together form both the framework and the insulation. (Balsa wood has the same insulation resistance as cork.)

This balsa insulation is lined inside and out with 5/16 inch of artificial stone made from a special waterproofed composition

with mangasite as the base. (This is the same composition that is used in the floors of subway cars, except that it is given an additional waterproofing treatment.)

The box is completely covered with white enamel paint, both inside and out.

(See pictures)

This box sells at retail for \$104. We understood from one of their employees that the factory cost is \$50.

We believe we could buy these boxes for \$90 in lots of 100, arranged for reception of the type OC-2 machine. Perhaps it will be necessary to strengthen the box in order to support the machine.

2. Rating of Machine: A machine with a rating of 30# of ice a day would easily refrigerate this box and make 12 ½# of ice on an average 70 deg. day.

However, in order to carry the peak load on a 90 deg. day, would require a rating of about 125# of ice a day.

The Fort Wayne type OC-2 machine has a rating of 167# of ice a day. This will be reduced by the changes necessary in air cooling, but will still be amply large. It is our understanding that it would be difficult to make a smaller machine at a lower cost.

3. Fundamental Types: The coefficient of performance of a refrigerating machine is the ratio of the refrigerating effect in B. t. u. divided by the energy required.

	<u>Coefficient of Performance.</u>
Theoretical Carnot Cycle 21 degrees F. to 82.5 degrees F.	7.81
Wet Compression SO(2) allowing for efficiency type OC-2 machine	.94
Intermittent Ammonia & Water Absorption Machine Without Precooler	.337
Intermittent Ammonia & Water Absorption Machine With Precooler	.455
Intermittent Ammonia with solid absorbent	.435
Compressed Air	.17

The above table gives a general idea of the relative efficiencies of the different methods of obtaining refrigeration.

The type OC-2 machine has an electrical input of .305 watt hours per B. t. u. of refrigeration. The electrical input expressed in B. t. u. is 1.07. Therefore, the coefficient of performance is about .94.

The intermittent absorption machines are thoroughly discussed in appendix #10, Vol. II, "Absorption Machines." It is hard to get

accurate data on these small machines. From a test published in Seibel's "Compend of Mechanical Refrigeration & Engineering", pages 454-455, it is shown that a 40 ton absorption machine shows an input in steam heat of 3.75 B.t.u. for each B.t.u. of refrigeration produced. This corresponds to a coefficient of performance of .265. It would be natural to expect that small machines would have a worse coefficient of performance. Therefore, the figures in the above table for absorption machines are probably too optimistic.

The coefficient of performance of the compressed air machine is calculated from the meager data we could obtain from the Automatic Refrigerating Company on their "Odin" machine. They told us the input was about 3 ½ KW-hours per day.

We calculated that their box would require 81 ½ B.t.u. per hour refrigeration. The combination of these two figures gives the coefficient of performance of .17.

Mr. R. W. Davenport of Detroit has suggested a system of refrigeration which is described in appendix #17. This is chiefly interesting because the Detroit Edison Company thinks so highly of it. We believe some experiments should be made along the lines suggested by Mr. Davenport.

4. Air or Water Cooled: This question is thoroughly discussed in appendix #9, Vol. II, "Redesign of Type OC-2 Machine for Air Cooling." Apparently the air cooled machine would require about \$1.30 more electricity in six months than the water cooled machine, but about 86 cents worth of water would be saved.

The air cooled machine is recommended on account of its greater simplicity.

5. Choice of Proper Refrigerant: In appendix #11, Vol. II, "Comparison of Various Refrigerants", the conclusion is reached that sulphur dioxide is probably the best refrigerant for the type OC-2 machine.

In a machine with no internal lubrication like the Savage Arms development, probably ethyl chloride would be preferable.

6. Type of Pump:

A. The oscillating cylinder pump used in the type OC-2 machine demonstrated its reliability throughout eleven years' operation in Audiffren machines. However, it does not have piston rings and the overall efficiency, including the motor, due to slippage and friction is only about 14 ½%. It also has the disadvantage that lubrication is required which makes an oil separator necessary.

B. The Coldak Company have a two stage herringbone gear, rotary pump which apparently has given good service. Most engineers are inclined to look askance at any form of rotary pump.

C. The Savage Arms Company have developed a rotary pump in the form of an Archimedes spiral through which mercury is caused to flow by centrifugal force.

For a description of this pump, see appendix #14, Vol. II, "Savage Arms Machine".

Mr. Goll, Mr. Blake, Mr. Dalton, Mr. Hewett and myself have all seen this pump and unanimously agree that it is of great interest.

It has the following advantages:

- a. No internal lubrication.
- b. No stuffing box.
- c. Probably 50% mechanical efficiency.
- d. Probably 100% volumetric efficiency.
- e. Impossible to blow up.
- f. It is hope that it could be made for a low cost.

If it is decided to enter the domestic refrigeration field, we strongly recommend that the Savage Arms Company be addressed with a view to obtaining a model for test and an option for a license.

D. Mr. Hewett has suggested a domestic refrigerating machine in which the gas is compressed by mean of an injector which is operated by mercury. The mercury is pumped by electromagnetic repulsion. This idea is old. Patent No. 757393, dated April 12, 1904, by Mr. Coleman, has already expired, covering this same scheme.

When we first heard of this scheme, we thought it was absolutely impracticable from the standpoint of efficiency, but Mr. Alger of the Induction Motor Department has calculated that he can make an electromagnetic mercury pump with an efficiency of 30%. We have been unable to find any experimental data as to the efficiency of a mercury injector, and because of the necessity of finishing this report quickly, there is no time to make any experiments along this line. If an injector could be made with a 50% #

Foot-note (#) : See next page.

efficiency, the overall efficiency of the electromagnetic pump and injector would be 15%. The present Fort Wayne type OC-2 machine has an overall efficiency of only 14.6%.

This type of pump would have the advantage that there would be no moving parts. This would eliminate both the problems of lubrication and noise.

Of course, even if such a scheme is ultimately possible, a great deal of research and development work will be necessary.

Although we believe there is only a slight chance of getting an injector with a sufficiently high efficiency, we believe that this investigation should be pushed far enough to show what the possibilities are.

- a. An electromagnetic mercury pump should be built in accordance with Mr. Alger's design.
- b. Experiments should be made to determine the efficiency of a mercury injector in compressing ethyl chloride vapor.

7. Conclusion:

The domestic refrigerating machine is still in the stage of engineering development.

Foot-note (#) on preceding page: When a steam injector is used for feeding water into a boiler, the thermal efficiency is nearly 100%, because the best content of the steam is returned to the boiler. But, when a steam injector is used for pumping water, the latent heat of condensation of the steam is wasted in uselessly warming up the water and the efficiency is from one to two percent. We have been unable to up to date to find any data on a mercury injector where the question of latent heat of condensation would not enter.

The Fort Wayne type OC-2 machine is sufficiently perfect for exploitation.

In the near future, something far superior may be found and if the General Electric hopes to lead, it will be necessary to spend about \$30,000. a year for the next five or ten years in further research and development.

REPORT #2
PARTS III & IV

MANUFACTURING AND FINANCIAL#

Introduction

It has been found impractical to separate the manufacturing discussion from the financial discussion, and they are both included in the following.

There are three general ways in which the General Electric Company might exploit a domestic refrigerating Machine.

1 – Probably the best method of exploitation would be as one of a “string of appliances manufactured by or for, and handled by a domestic appliance corporation. However, it would be outside the scope of this report to attempt to analyze the proportion of the expenses of such a corporation which should be allotted to the domestic refrigerating machine business.

2 – The General Electric Company might simply manufacture the machines at their Fort Wayne Works and sell them to some subsidiary company or departmental organization to exploit domestic refrigerating machines.

3 – A separate company might be organized to manufacture and exploit these machines.

The second case lends itself to a clearer analysis than either of the others.

The Fort Wayne Works are already organized to manufacture the Audiffren machine. By a rearrangement the domestic ice machines could very easily be manufacture along with the Audiffren machines for the first few years, without much increase in space.

The items of expense in the manufacture of the Audiffren are well known, and we therefore feel that a more accurate estimate of the cost of manufacture of the domestic machine can be made by assuming that the Fort Wayne Works will consolidate their manufacture along with the Audiffren machines.

This had the added advantage that the increased production secured by a consolidation of these two lines of apparatus in the same shop will distribute the factory overhead over a large volume of business and thus tend to lower the percentage which must be charged against each machine.

The sales of these machines should be made by a domestic appliance company. But, such a company does not yet exist and, as mentioned earlier, the organization of a large domestic appliance company is beyond the scope of this report.

In order to make a clear profit and loss statement, it is assumed that the domestic refrigerating machines will be sold through a separate subsidiary company or departmental organization, which will be described in detail further on.

It seems evident that if certain results can be obtained in the first few years' operation of small separate company or departmental organization, better results could be

obtained as part of a large domestic appliance company where the general office expenses would be absorbed by larger gross sales.

It is not recommended that manufacture and exploitation be started immediately. Some preliminary development work and factory rearrangement is required. The present OC-2 machine is water cooled, and although we are confident that it can be easily redesigned for air cooling, it is conservative to assume that six or eight months will be required to produce, test, and prove a model, satisfactory in all its details. It is also felt that business conditions will be more favorable for exploitation in 1925 than in 1924.

The Fort Wayne Works has an unexpended balance for the developmental work on the type OC-2 machine of about \$10,000. This makes it possible to start the development of an air cooled design immediately.

The detailed explanation of expenditures follows the outline of operations.

TABLE I: Development Account.

TABLE II: Manufacturing.

It is assumed that the manufacturing will be done by the Fort Wayne Works.

TABLE III: General Expenses of subsidiary sales company or departmental organization.

There will be no General Office for the first two years. The District Manager of the New York Office of the domestic refrigerating machine sales organization will act as General Sales Manager.

TABLE IV: District Sales Expenses.

TABLE V: Summary.

TABLE VI: Summary.

At the head of each column in each of these tables there is a capital letter which indicates the schedule on which an explanation of the items can be found. When the same column is repeated on more than one table, the same letter is used. There were not enough letters in the alphabet for these different columns, and the latter few are given double letters.

TABLE I.

DEVELOPMENT ACCOUNT

Previous Development Expended on Type OC-2 Water Cooled Machine - \$88,547 (to June 25, 1923

	A	B	C	D	E	F
	Development	Patterns &	Complaint	Applied App.	Total	% of Factory
<u>Year</u>	<u>&Research</u>	<u>Special Tools</u>	<u>Expenses</u>	<u>Expenses</u>	<u>Expense</u>	<u>for Year</u>
<u>Billing</u>						
One year Dev. period	\$17500 a	\$15000	\$ ----	\$ ----	\$32500	----
1 st year of expenditures	10000	5000	1550	10700 b	27250	146.0%
2 nd year of expenditures	10000	5000	7750	10000	32750	17.6%
3 rd year of expenditures	10000	10000	21000	10000	51000	10.1%
TOTAL	\$47500	\$35000	\$30300	\$30700	\$143500	20.3%
Percent of Factory Billing	6.7%	4.9%	4.3%	4.4%	20.3%	

Total development, including that previously expended on the water cooled machine, is \$232,047, which equals 32.9% of the total factory billing for three years.

a This includes \$5,00 for the purchase and test of competing machines.

b This includes \$5,700 which is the difference between the actual factory cost for the first 100 machines and the amount billed by the factory.

TABLE II.

MANUFACTURING

	G	H	I	IA	IB	IC
Year	Rearrangement of Buildings etc Billing	Manufactur- ing cost	Factory Cost of Machines Billed	Allocations of Corporate Expenses	Manufac- of G.E. Co. Profit	Factory General
One year Dev. period	\$1200	\$5000 a				
1 st year of expenditures		16200 5700 b 52000 a	15500	1550	1550	18600
2 nd year of expenditures		103000 140000 a	155000	15500	15500	185000
3 rd year of expenditures	60000	280000 260000 c	420000	42000	42000	504000
TOTAL	\$61200	\$590500	\$590500	\$30700	\$59050	\$708600
Percent of Factory Billing	10.4%	100%	100%	10%	10%	120%

- a Expended on partial manufacture of machines for shipment during the next year.
- b Excess cost of manufacture while mechanics are being trained. This is charged to development under the sub-head "Applied Apparatus Expense" and is therefore subtracted in the total at the bottom of the Manufacturing Cost column.
- c. This represents the Material & Apparatus Inventory at the end of the third year and is therefore not included in the total at the bottom of the column of Manufacturing Cost.

TABLE III.

GENERAL EXPENSES

	J	K	L	M	N	NA	S	T
		Personal	Office	Office	Adver-	Allocations of G.E.		Total general
Year	Salaries	Expenses	Rent	Expenses	tising	Co. General	Corpo-	Expense expressed
						rate	expenses	as a % of
								factory billing
							Total	
One year Dev. period								
1 st year of expenditures					\$1000		\$930 b	\$1930 10.4%
2 nd year of expenditures	c	c	c	c	10000		9300 b	19300 10.4%
3 rd year of expenditures	\$10400	\$2000	\$1000	\$500 1500 a	30000		25200	70600 13.8%
TOTAL	\$10400	\$2000	\$1000	\$2000	\$41000		\$35450 b	\$91830 12.96%
Percent of Factory Billing	1.47%	.28%	.14%	.28%	5.8%		5% b	12.96%

a This is office furniture and fixtures.

b General Corporate Expenses of the G.E. Co, accessible to distributing organization, are assumed to be 5% of the factory billing.

c. During the first two years, while sales are concentrated in one city, these expenses are included with the district office expenses.

TABLE IV.

DISTRICT SALES EXPENSES

	U	V	W	X	Z	AA	BB	CC
		Personal	Office	Office	Instal-			% of Sales
Year	Salaries	Expenses	Rent	Expenses	lation	Service	Total	Billed
One year Dev.period								
1 st year of expenditures	\$16400	\$6000	\$2000	\$1000 \$ 2000 a	\$6000	\$600	\$34000	67.2%
2 nd year of expenditures	65400	26450	4000	2000 1500 a	40000	2000	141350	28.7%
3 rd year of expenditures	196200	79350	12000	6000 7000 a	120000	6000	426550	31.0%
TOTAL	\$278000	\$111800	\$18000	\$19500	\$166000	\$8600	\$601900	31.6%
Percent of Factory Billing	1.4.64%	5.85%	0.94%	1.02%	8.7%	0.45%	31.0%	

a Office furniture and fixtures purchased during the year

TABLE V.

SUMMARY

	DD	IC	S	E	EE	FF	?	GG	HH	II
	Number of			Expend.	Profit				Partial Liq.	Accum.
Year	Machines	Factory	General	for	or	Refrig	District	Sales	of Prev.	Profit
	Sold	Billing	Expense	Devel	Loss	Boxes	Expense	Billed	Devel.	or Loss
One year Dev. period				\$32500 b					-32500 b	
1 st year of expenditures	100	\$18600	\$1930	27250 b	-13125	9000	34000	50405	-27250 b	Loss 13125
2 nd year of expenditures	1000	186000	19300	32750	20850	80000	141350	480250	7725	-----
3 rd year of expenditures	3000	504000	70600	51000	114850	210000	426550	1377000	114850	-----
TOTAL	4100	\$708600	\$91830	\$145500 d	\$122575	\$299000	\$601900	\$1907555	\$62825 d	
			13% a	20.3% a	15.2% e	15.7% c	31.6% e		8.9% a	

a This is percentage of Factory Billing

b These items of development are not included in the sales price but are charged to the development account

c This is percentage of sales billed. D

d The sum of the columns Expenditure for Development and Partial Liquidation of Previous Development is \$205,824. The total development is this sum plus \$25,722, the unliquidated development at the end of the third year, or \$232,047., which is 32.9% of the Factory Billing. E

e This is a percentage of the Gross Cost. The gross cost is the sum of column "I" and column "S"

TABLE VI.

SUMMARY

	JJ	KK	Q	O & P	II	LL	MM	NN
		Factory		Notes to	Accum-	#	Avg. In-	Profit Ex.
		Inventory		come due	lated		vestment	as % of the
	Unliq.	Material	Cash	Goods in Transit	Profit	Lockup at	Throughout	Average
Year	Develop.	& Apparatus	Balance	& Accts. Rec.	or Loss	end of year	the year	Investment
One year								
Dev.period	\$121047 a	\$5000				\$125047 a	\$107297 a	
					Less			
1 st year	148297	52000	\$5000	\$9950	\$13025	228272	177159	-7.4%
2 nd year	140572	140000	30000	95500	-----	405072	317172	+6.0%
3 rd year	25722	260000	80000	266000	-----	631722	518897	+22.3%
							1120525	
						Four years' average investment	\$280131	
						Four years' average profit	30644	
						Four years' average profit	10.8%	

a This includes \$88547 previously expended for development of water cooled machine.

This does not include the lockup in manufacturing equipment, catalogue tools, etc. It is assumed that the G.E. Co's 10% manufacturing profit will pay the interest on the investment in manufacturing facilities.

SCHEDULE "A".

DEVELOPMENT AND RESEARCH

August 1, 1923

One Year's Developmental Period.

The following facilities are necessary for the development and testing of an air cooled model of the type OC-2 refrigerating machine:

Partitions and necessary equipment for heating Hot Room - -	\$ 500
Switchboard and necessary electrical openings- - - - -	200
Recording thermometers and equipment for recording temp. -	200
Incidental fixtures and tools including benches, test stands, brine tanks, and circulating pumps - - - - -	<u>200</u>
TOTAL - - - -	\$ 1100

In addition to the above we will require approximately 720 square feet of floor space.

One vacuum pump.

One air compressor.

If it is possible to get space in the present building for this room, the present vacuum pump and air compressor can be used.

(Continued on following page)

It is felt that at least six (6) models of the air cooled type OC-2 machine should be made, three of them for extensive factory tests and three for installation in the houses of some of those interested in Fort Wayne.

Approximate Cost of Building the Necessary Patterns and Building Six (6) Models of the Proposed Air Cooled OC-2 Refrigerating Machine:

Building three (3) new patterns and making the necessary changes in the present patterns - - - - -	\$ 625
Drafting and Engineering- - - - -	2500
Building first three (3) models - \$600 each - - - - -	1800
Three (3) remaining models - \$400 each - - - - -	1200
Testing - \$200 each - - - - -	1200
Changes due to changes in design and other causes - - - - -	900
\$150 each	
Installation and service for three (3) machines to be installed outside the Works - \$130 each - - - - -	<u>390</u>
TOTAL - - - - -	\$ 8615

(Continued on following page)

It will be noted that the total cost of facilities and developmental work on the air cooled machine is \$9,715. We have, therefore, assumed that \$10,000 will complete the development of the air cooled machine ----- \$ 10 000

This work will take from six months to a year. At the same time it is recommended that models of competing machines be purchases and tested. This will cost about -- \$ 5 000
 Miscellaneous engineering expenses ----- \$ 2 500
 TOTAL ----- \$17 500

First year exploitation, general development and research	\$10 000
Second year “ “ “ “ “ “	10 000
Third year “ “ “ “ “ “	10 000

SCHEDULE “B”

PATTERNS AND SPECIAL TOOLS

During the preliminary developmental year preparations will be made for the manufacture of 100 machines. This will require patterns, tools, assembly equipment, test equipment, hydrogen furnace, suaging machine, etc. ----- \$ 15 000

During the first year exploitation -
 Additional tool equipment ----- \$ 5 000

During the second year exploitation –
 Additional tool equipment ----- \$ 5 000

During the third year exploitation –

Preparations will be made for manufacture

in lots of 5,000

Special tool equipment ----- \$10 000

This covers only special tools and equipment of a developmental nature and does not include general purpose machine tools, which latter it is assumed the Fort Wayne Works will provide, either by transfer from other departments or by purchase, as may be necessary.

SCHEDULE "C"

COMPLAINT EXPENSES

Preliminary year – no complaint expenses.

First year –

10% of Factory billing ----- \$ 1 550

Second year –

5% of Factory billing ----- \$ 7 750

Third year –

5% of Factory billing ----- \$ 21 000

NOTE: It should be noted that the district office bears part of the complaint expenses as shown in column "AA", and also the salaries of the service men, which are included in column "U".

SCHEDULE "D"

APPLIED APPARATUS EXPENSES

Preliminary year – none.

First year – assumed ----- \$10 700 *

Second year – assumed ----- \$10 000

Third year – assumed - - - - - \$10 000

* This includes \$5,700 which is the difference between the actual factory cost of the first 100 machines and the amount billed by the factory.

SCHEDULE “E”

TOTAL FOR YEAR

This column is the sum of columns “A”, “B”, “C”, and “D”.

SCHEDULE “F”

PER CENT OF FACTORY BILLING

This column is the quotient of column “E” divided by Column “IC”, expressed as a percentage.

SCHEDULE “G”

REARRANGEMENT OF BUILDINGS, ETC.

During the year of preliminary development it will be necessary to rearrange the present Ice Machine department of the Fort Wayne Factory. This will consist of rearranging the machinery, the wiring, and constructing a partition.

TOTAL COST - - - - - \$ 1, 200

NOTE: The ice machine department at the Fort Wayne Works now occupies the first floor and basement of Building 12, which given available manufacturing space of 14,400 square feet. The pattern shop and pattern storage occupies the second and third floors of this building, equaling 19,200 square feet.

The present space is sufficient for the manufacture of the Audiffren machines and 100 domestic machines per year, and a slight rearrangement will provide sufficient space for 1000

domestic machines required in the second year.

For the 3000 domestic machines required in the third year and the Audiffren production there will be required a total of 34,000 square feet, which is practically the total area of Building 12.

This will necessitate providing approximately 20,000 square feet additional for pattern shop and pattern storage. The cost of this extra 20,000 square feet will probably be \$60,000.

(Continued on following page)

It should especially be noted that the interest on buildings, catalogue tools, etc., it is not included in the accounts shown in the following tables, because it is assumed that the Fort Wayne factory will include this interest charge in the cost at which the machines are billed.

Column "G" was included merely by way of mentioning these items, for fear it should be supposed that they had been entirely overlooked.

SCHEDULE "GG"

SALES BILLED

The sales billed is taken from Table I of Part II of Report #2, page 4, after deducting a 15% discount for the central station as explained in schedule "Y".

SCHEDULE "HH"

LIQUIDATION OF PREVIOUS DEVELOPMENT

During the preliminary year the development acct. increased \$ 32 500.

During the first year the development account increased \$ 27 250.

During the second year the whole accumulated profit of \$ 7,725 was used to liquidate some of the previous development.

During the third year the whole of the accumulated profit, \$114,850, was used to liquidate most of the remaining development account. (See schedule "JJ")

SCHEDULE "II"

ACCUMULATED PROFIT OR LOSS

In this column is shown the loss of \$13,125 during the first year.

In the second year there was no accumulated profit, because the surplus profits were all used to liquidate development.

In the third year, there was no accumulated profit, because the surplus profits were all used to liquidate development.

SCHEDULE "H"

MANUFACTURING COST

During the year of preliminary development work was started on a lot of 100 machines at an estimated cost of \$200 each.

Preliminary year –

At the end of the year this work was 25%
completed. Expenditure - - - - \$5 000

First year –

During the first year of exploitation this
lot of 100 machines was completed. Expenditures - - \$15 000

Extra Contingencies - - - - 1 200

This made a total cost for the 100 machines of - \$21 200

The machines were billed by the factory at - \$15 500

Difference - - - - \$ 5 700 *

* Four years' average profit This difference was charged to the development account under the heading "Applied App. Expend."

Toward the end of the year work was one-third completed on a lot of 1000 machines at an estimated cost of \$155 each - - - - \$52 000

Second Year –

Lot of 1000 machines completed - - - \$103 000

One-third completion of a lot of 3000 machines
at \$140 each - - - - - \$140 000

Third year –

Completion of lot of 3000 machines - - - \$280 000

One-third completion of a lot of 6000 machines
at \$150 each - - - - - \$260 000

(Continued on following page)

NOTE: Boxing of these machines would cost between \$2.00 and \$3.00 each, and it is assumed that this is included in the cost at which the machines are billed.

The Fort Wayne factory have estimated that with rapid production the type OC-2 air cooled machine can be made in lots of 100 as follows:

MATERIAL	-	-	-	- \$ 86.74
LABOR	-	-	-	- 28.16
140% EXPENSE	-	-	-	- <u>39.42</u>
			Total	- \$154.32

Of this cost \$8.86 is the motor, and \$28.26 is the automatic control.

It will be noted that during the first year it has been assumed that a lot of 100 machines would actually cost about \$200 each. During the second year a lot of 1000 machines would actually cost about \$155 each. During the third year a lot of 3000 machines would actually cost \$140 each. And during the fourth year a lot of 6000 machines would actually cost \$130 each.

SCHEDULE "I"

FACTORY COST OF MACHINES BILLED

Preliminary year – None.

First year	- 100 machines at \$155.	-	-	-	- \$ 15 500
Second year	- 1000 machines at \$155.	-	-	-	- \$155 000
Third year	- 3000 machines at \$140.	-	-	-	- \$420 000

SCHEDULE "IA"

ALLOCATION OF GENERAL ELECTRIC COMPANY'S CORPORATE EXPENSES.

It is assumed that part of the general corporate expenses of the General Electric Company will be assessed against the manufacture of these machines. Since the commercial overhead on apparatus shipped to the Western Electric Company is only 9%, we believe that we are justified in assuming this allocation of expenses to the Ice Machine Department of the Fort Wayne Works will not be more than 10% of the factory cost.

SCHEDULE "IB"

MANUFACTURING PROFIT.

If a separate subsidiary company is organized to sell the domestic refrigerating machines, it would be necessary for the General Electric Company to take a manufacturing profit. So many contracts are done on a "cost plus 10%" basis, that we have assumed a 10% manufacturing profit would make a suitable return on the investment in factory buildings, catalogues tools, etc.

SCHEDULE "IC"

FACTORY BILLING

This is the sum of columns "I", "IA", "IB", and "IC".

Preliminary year – None.

First year	-	100 machines at \$186.	-	-	- \$ 18 600
Second year	-	1000 machines at \$186.	-	-	- \$186 000
Third year	-	3000 machines at \$168.	-	-	- \$504 000

SCHEDULE "J"

SALARIES CHARGED TO GENERAL EXPENSE

During the first several years no general office would be necessary. The Sales Manager of the district office would perform the duties of General Sales Manager. However, in the third year, there would be three district offices in New York, Boston, and Philadelphia, and a general office would be set up in Fort Wayne, the pay roll of which would be as follows:

General Manager	-	-	- \$7 000
Stenographer	-	-	- \$1 000
Bookkeeper	-	-	- \$2 400

SCHEDULE "K"

PERSONAL EXPENSES

During the third year, the expenses of the General Manager would be \$2000.

SCHEDULE "L"

OFFICE RENT

During the third year, the rent of the office space for the General Manager in Fort Wayne would be \$1000.

SCHEDULE "M"

OFFICE EXPENSES

During the third year, the expenses of the general office in Fort Wayne for stationary, stamps, telephone, telegraph, light, and miscellaneous, would be \$500. Office furniture and fixtures would have to be purchased at \$1500.

SCHEDULE "N"

ADVERTISING

During the first year, \$100 would be spent on local advertising

in New York. During the second year, \$10,000 would be spent on local advertising in New York. During the third year, \$10,000 would be spent in each of the three cities, New York, Boston, and Philadelphia.

SCHEDULE "NA"

ALLOCATION OF GENERAL ELECTRIC COMPANY'S GENERAL CORPORATE EXPENSES CHARGED TO SEPARATE SUBSIDIARY COMPANY OR DEPARTMENTAL ORGANIZATION

Since some of the General Electric corporate expenses have already been included in Schedule "IA" where an allotment equal to 10% of the manufacturing cost was charged to the Ice Machine Department of the Fort Wayne Works, it is assumed that the selling organization will not be charged with allocations of the General Electric Company's general corporate expenses, amounting to more than 5% of the factory billing.

SCHEDULE "O"

GOODS IN TRANSIT AND
IN THE WAREHOUSE

First year – 100 machines each in transit and in warehouse
30 days - - 8 1/3 machines in transit at the same
time, valued at \$186. each.

Total average value of goods in transit and in
the warehouse throughout the year - - - - - \$ 1 550

Second year – 1000 machines each in transit and in warehouse

30 days - - 83 1/3 machines in transit or warehouse at the same time at \$186. each.

Total average value of machines in transit or in the warehouse throughout the year - - - - - \$15 500

Third year – 3000 machines each in transit and in warehouse
23.7 days - - 214 machines in transit or warehouse at the same, time at \$168. each.

Total average value of machines in transit and in the warehouse throughout the year - - - - - \$36 000

SCHEDULE “P”

ACCOUNTS RECEIVABLE

First year – 100 accounts receivable for 60 days
at \$504 each - - 16 2/3 accounts receivable at one time.

Total average value throughout the year - - - \$ 8 400

Second year – 1000 accounts receivable for 60 days
at \$480 each - - 166 2/3 accounts receivable at one time.

Total average value throughout the year - - - \$ 80 000

Third year – 3000 accounts receivable for 60 days
 at \$459 each - - 500 accounts receivable
 at one time.

Total average value throughout the year - - - \$230 000

SCHEDULE “Q”

CASH BALANCE

First year – Since the sales billed are \$50,405 it would
 be reasonable to carry a cash balance of - - \$ 5 000

Second year – Sales billed - - - - - \$480 250
 assumed cash balance- - - - - \$ 30 000

Third year – Sales billed - - - - - \$1 377 000
 assumed cash balance- - - - - \$ 80 000

SCHEDULE “R”

UNLIQUIDATED DEVELOPMENT

Column “T” is column “S” expressed as a percentage of
 column “IC”.

SCHEDULE “U”

DISTRICT OFFICE SALARIES

First year –	one district manager	-	-	-	- \$ 5 000
	two salesmen at \$4 000-	-	-	-	- 8 000
	one bookkeeper-	-	-	-	- 2 400
	one stenographer-	-	-	-	- <u>1 000</u>

			TOTAL	\$16 400
Second year – District Manager-	-	-	-	- \$ 5 500
twelve salesmen at \$4 000-	-	-	-	- 48 000
one bookkeeper-	-	-	-	- 2 400
two stenographers-	-	-	-	- 2 000
three service men at \$2 500	-	-	-	- 7 500
Third year – Three district offices, each with a staff similar to the one described above.				
	Total salaries-	-	-	- \$196 200

SCHEDULE “V”

DISTRICT OFFICE PERSONAL EXPENSES

First year – Manager and each of two salesmen spend \$2000.	Total	-	-	-	- \$ 6 000
Second year – Manager and each of twelve salesmen spend \$2000.	Total	-	-	-	- \$ 26 000
Three service men \$150 each		-	-	-	- \$ 450
Third year – Three offices just like the one we had the second year.	Total personal expenses				-\$ 79 350

SCHEDULE “W”

DISTRICT OF OFFICE RENT

First year – 800 sq. ft. of floor space, New York					
City, at \$2.50 per sq. ft.	-	-	-	-	-\$ 2 000
Second year – 1600 sq. ft. of floor space, New York					
City, at \$2.50 per sq. ft.	-	-	-	-	-\$ 4 000
Third year – Offices in New York, Philadelphia, and					

Boston - - - - - \$ 12 000

SCHEDULE "X"

DISTRICT OFFICE EXPENSES

First year – Stationery, stamps, telephone, telegraph,

light, and miscellaneous - - - - \$ 1 000

Purchase of office furniture & fixtures- - \$ 2 000

Second year – Stationery, stamps, & etc. - - - - \$ 2 000

Additional furniture & fixtures - - - - \$ 1 500

Third year – Stationery, stamps, & etc. - - - - \$ 6 000

Additional furniture & fixtures for two
now district offices - - - - \$ 7 000

SCHEDULE "Y"

COMMISSIONS TO CENTRAL STATIONS

In order to enlist the cooperation of the central stations, it is recommended that the selling organization sell the domestic refrigerating machines to the central stations at a 15% discount. This 15% discount will repay the central stations for showroom facilities, good will, and general commercial assistance. In addition, the central station will finance any time payment plans, and their Credit Department will attend to the collection of bills.

The selling organization will take care of all other expenses. Their salesmen will sell the machines and their service men will furnish any necessary service. However, when a salesman has sold

the machine, he will turn the order over to the central station, after which, if the central station's Credit Department is satisfied with the customer's credit, the central station will bill the machine to the customer.

The central station will not have to either deliver the machine or install it, since this will be taken care of by the selling organization.

SCHEDULE "Z"

EXPENSES IN CONNECTION WITH INSTALLATION

The freight on each machine installed varies from \$1.75 per machine in carload lots to perhaps \$5.00 per machine

L.C.L.-	-	-	-	-	-	-	- \$ 1.75
Truck driver and assistant for one day -	-	-	-	-	-	-	8.00
Truck rent for one day -	-	-	-	-	-	-	10.00
Special wiring -	-	-	-	-	-	-	30.00
Warehouse charge -	-	-	-	-	-	-	<u>2.00</u>
						TOTAL -	\$ 51.75

The first year we assumed this as \$60.00 and the second and third years we assumed that it could be reduced to \$40.00
 NOTE: The first year one of the salesmen acts as a service man, and superintends the installation. The second and third years the regular service men superintend the installation.

It should be pointed out that so many men are necessary because there is a good deal of lifting to be done on placing the refrigerator box in the house and placing the machine in the box.

SCHEDULE "AA"

SERVICE

First year – If 10 machines were shipped back to factory
the replacing of them would cost the district
office at least \$60 each, in addition to the
service man's pay, which is included under
Salaries, equals - - - - - \$ 600

Second year – Fifty machines shipped back to factory, re-
placement cost at \$40 each equals - - - \$2 000

Third year – One hundred fifty machines shipped back to
factory, replacement cost equals - - - \$6 000

SCHEDULE "BB"

TOTAL

Column "BB" is the sum of "U", "V", "W", "X", "Z", and "AA".

SCHEDULE "CC"

PERCENT OF SALES BILLED

Column "CC" is column "BB" expressed as a percentage of column "GG"

SCHEDULE "DD"

NUMBER OF MACHINES SHIPPED

The number of machines shipped is taken from Table in Part II
of report II, page 4.

SCHEDULE "EE"

PROFIT OR LOSS

This is obtained by subtracting columns "I", "S", "E", "FF",

“BB”, from column “GG”, with the exception that during the first year column “E” is charged to the development account.

SCHEDULE “FF”

REFRIGERATOR BOXES

First year – 100 boxes at \$90	-	-	-	-	\$ 9 000
Second year – 1000 “ ” \$80	-	-	-	-	\$ 80 000
Third year – 3000 “ ” \$70	-	-	-	-	\$210 000

SCHEDULE “JJ”

UNLIQUIDATED DEVELOPMENT

Previous development on water cooled machine	-	-	-	-	\$ 88 547
Expenditures during preliminary year	-	-	-	-	<u>32 500</u>
Total at beginning of first year’s exploitation-	-	-	-	-	\$ 121 297
Additional development during first year	-	-	-	-	27 250
Total at beginning of second year	-	-	-	-	\$ 148 297

During the second year \$27,528 was spent on development, but this was all charged to sales.

Previous development liquidated by surplus profits	-	-	-	-	<u>\$ 7 725</u>
Balance at beginning of third year	-	-	-	-	\$140 572

During the third year there was spent for development \$51,000, but this was all charged against sales.

Liquidated from profits	-	-	-	-	<u>\$114 850</u>
Development at beginning of fourth year	-	-	-	-	\$ 25 722

SCHEDULE “KK”

FACTORY INVENTORY – MATERIAL & APPARATUS

End of preliminary year	-	-	-	-	-	-	\$ 5 000
End of first year’s exploitation	-	-	-	-	-	-	\$ 52 000
End of second year’s exploitation	-	-	-	-	-	-	\$140 000
End of third year’s exploitation	-	-	-	-	-	-	\$260 000

We have charged the investment in factory inventory to the subsidiary domestic refrigerating machine company, or departmental organization. Perhaps this should have been included in the manufacturing facilities, in which case the return on this investment would have been included in the 10% manufacturing profit. However,

it seems more conservative to include this inventory in the investment charged against the subsidiary company or departmental organization selling the machines.

SCHEDULE “LL”

LOCKUP

This is the algebraic sum of “JJ”, “KK”, “Q”, “O &P”, and “II”. This shows the amount of General Electric Company money which would be tied up at the end of each year, but does not include the capital investment in factory buildings and catalogue tools.

SCHEDULE “MM”

AVERAGE INVESTMENT THROUGHOUT THE YEAR

At the beginning of one years developmental

period the investment consisted merely in the amount

previously expended for development, namely - - - - \$ 88 547

At the end of one year's developmental period, the

lockup had increased to - - - - - - \$126 047

The average lockup throughout the one year's development

period was - - - - - - - \$107 297

One year's exploitation:

At the beginning, the lockup was - - - - - - \$126 047

At the end of the year, the lockup was - - - - - - \$228 272

Average lockup throughout the year - - - - - - \$177 159

Second year's exploitation:

At the beginning, the lockup was - - - - - - \$228 272

At the end of the year, the lockup was - - - - - - \$406 072

Average lockup throughout the year - - - - - - \$317 172

Third year's exploitation:

At the beginning, the lockup was - - - - - - \$406 072

At the end of the year, the lockup was - - - - - - \$631 722

Average lockup throughout the year - - - - - - \$518 897

Average lockup throughout the four years - - - - - - \$280 131

Distributing the total profits through the four years given in

annual average profit of \$30,644. Therefore, the average investment throughout one year's developmental period and three years' exploitation would be \$280,131, and the average return during these four years would be 10.8% per annum.

SCHEDULE "NN"

PROFIT EXPRESSED AS A PERCENTAGE OF THE AVERAGE INVESTMENT

This is obtained by expressing column "EE", table V, as a percentage of column "MM", table VI.

ANALYSIS OF PRICE
First Year's Exploitation

Manufacturing cost	-	-	-	-	-	- \$ 155.00)
Allocations of G.E. Co. General Corporate Expense, 10%	-	-	-	-	-	- 15.50) Table II
Manufacturing profit to cover investment in plant facilities, 10%	-	-	-	-	-	- <u>15.50</u>)
Factory bills machine at	-	-	-	-	-	- \$ 186.00
General Commercial expense of subsidiary company or departmental organization, 10.4%	-	-	-	-	-	- <u>19.30</u> Table III
Gross Commercial cost (not including development)	-	-	-	-	-	- \$ 205.30
Loss, 64% of gross commercial	-	-	-	-	-	- <u>131.25</u> Table V
District pays for machine	-	-	-	-	-	- \$ 74.05
District pays for refrigerator box	-	-	-	-	-	- <u>90.00</u> Sched. FF
						\$ 164.05
District selling expense, 67.2% of selling price to central station	-	-	-	-	-	- <u>340.00</u> Table IV
Selling price to central station-	-	-	-	-	-	- \$ 504.05
Discount to central station	-	-	-	-	-	- <u>88.95</u> Sched. Y
Total selling price to ultimate customer	-	-	-	-	-	- \$ 593.00
Loss on 100 machines at \$131.25	-	-	-	-	-	- \$ 13,125.
Increase in unliquidated development	-	-	-	-	-	- <u>32,500.</u>
Total loss, if increase in development is included	-	-	-	-	-	- \$ 45,625.

ANALYSIS OF PRICE

Second year's exploitation.

Manufacturing cost	-	-	-	-	-	- \$ 155.00)
Allocations of G.E. Co. General Corporate							
Expense, 10%	-	-	-	-	-	15.50	) Table II
Manufacturing profit to cover investment							
in plant facilities, 10%	-	-	-	-	-	<u>15.50</u>)
Factory bills machine at	-	-	-	-	-	\$ 186.00	
General Commercial expense of subsidiary							
company or departmental organization,							
10.4%	-	-	-	-	-	<u>19.30</u>	Table III
Gross Commercial cost (not including							
development)	-	-	-	-	-	\$ 205.30	
Profit, 10.2% of gross commercial	-	-	-	-	-	20.85	Table V
Development, 17.6% of factory billing	-	-	-	-	-	<u>32.75</u>	Table I
District pays for machine	-	-	-	-	-	\$ 258.90	
District pays for refrigerator box	-	-	-	-	-	<u>80.00</u>	Sched. FF
						\$ 338.90	
District selling expense, 28.7% of selling							
price to central station	-	-	-	-	-	<u>141.35</u>	Table IV
Selling price to central station-	-	-	-	-	-	\$ 480.25	
Discount to central station, 15%	-	-	-	-	-	<u>84.75</u>	Sched. Y
Total selling price to ultimate customer	-	-	-	-	-	\$ 565.00	
Profit on 1000 machines at \$20.85	-	-	-	-	-	\$ 20,850.	
Liquidation of previous year's loss	-	-	-	-	-	<u>13,125.</u>	
						\$ 7,725.	
Partial liquidation of previous development	-	-	-	-	-	<u>7,725.</u>	
Accumulated profit or loss	-	-	-	-	-	\$ -----	

ANALYSIS OF PRICE
Third Year's Exploitation

Manufacturing cost	-	-	-	-	-	- \$ 140.00)
Allocations of G.E. Co. General Corporate						
Expense, 10%	-	-	-	-	-	14.00) Table II
Manufacturing profit to cover investment						
in plant facilities, 10%	-	-	-	-	-	<u>14.00</u>)
Factory bills machine at	-	-	-	-	-	\$ 168.00
General Commercial expense of subsidiary						
company or departmental organization,						
13.8%	-	-	-	-	-	<u>23.53</u> Table III
Gross Commercial cost (not including						
development)	-	-	-	-	-	\$ 191.53
Profit, 20% of gross commercial	-	-	-	-	-	38.28 Table V
Development, 10.1% of factory billing	-	-	-	-	-	<u>17.00</u> Table I
District pays for machine	-	-	-	-	-	\$ 246.81
District pays for refrigerator box	-	-	-	-	-	<u>70.00</u> Sched. FF
						\$ 316.81
District selling expense, 31% of selling						
price to central station	-	-	-	-	-	<u>142.19</u> Table IV
Selling price to central station-	-	-	-	-	-	\$ 459.00
Discount to central station, 15%	-	-	-	-	-	<u>81.00</u> Sched. Y
Total selling price to ultimate customer	-	-	-	-	-	\$ 540.00
Profit on 3000 machines at \$38.28	-	-	-	-	-	-\$114,850.
Partial liquidation of previous development	-	-	-	-	-	114,850.
Accumulated profit or loss	-	-	-	-	-	-\$ -----

DOMESTIC REFRIGERATION

February 14, 1925.

SUPPLEMENT TO
REPORT OF AUGUST 27, 1924, AND PRECEDING REPORTS

Compiled and written by

Walter Goll.

A.R. Stevenson, Jr.

Concurred in
H. E. Crane
Clark Orr
R. Steck
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<u>INDEX</u>	<u>PAGE</u>
Introduction	1
History	2
Description	3
Installation	4
Service	5
Reliability	6
Protection	7
Capacity and Economy	7
Energy Consumed	8
Development	9
Costs	9
Prices	10
Comparison with prices of other machines	10
Program	11
Conclusion	12

REPORT ON TYPE OC-2 DOMESTIC
REFRIGERATING MACHINE
AIR COOLED

(Supplementary to Report of Aug. 27, 1924 and preceding reports).

The development of this machine has progressed to such a point that it is now deemed proper to undertake the manufacture and sale during the next six months of one hundred machines, in order that valuable experience may be gained. The present design has many advantages and some disadvantages as compared with other machine now on the market, but as a whole we consider it a superior design. There are only two features in this design concerning which we feel some uncertainty. These are noise and insulation. The noise is somewhat greater than that of an electric fan and considerably less than that of a vacuum cleaner or an oil burner. Continued efforts are being made to improve this feature. However, the woman in whose homes these machines are installed do not consider the noise a serious objection. It compares favorable in this respect with competing machines.

In some of the water cooled machines there were insulation failures but additional insulation and winding space provided in a re-design of the motor, together with an improved treatment of the coils, will, we believe, satisfactorily solve this problem. Sufficient time has not elapsed since these changes were adopted to demonstrate how long this insulation will last but we have reason to anticipate a life of ten years. At this point in our development it seems proper to review briefly the facts upon which we base our recommendations.

HISTORY

The Audiffren machine has been built for about twenty-six years past in France, and for a dozen years here at Fort Wayne Works. This Fort Wayne production has shown a complaint expense of 2.6% of factory cost for the past eight years. About 1917 the engineers undertook to apply their many years experience with the Audiffren machine to the development of a domestic device. After several years experiment they produced the Type OC-2 machine, water cooled, and with the motor totally enclosed within the machine housing. In the early part of 1921 about twenty-five of these machines were installed in the homes of G. E. employees at Fort Wayne and Schenectady. Very few of these machines remain in service, most of them having been returned to the factory, but the experience gained has been invaluable in perfecting the design.

In August, 1923, work was started on the redesign for air cooling. This change presented many new problems not thereto fore encountered, which have been successfully solved. The present design is the result of an intimate experience with machines and problems of like character, antedating probably the experience of any other domestic refrigerating company now in the market.

DESCRIPTION

This design consists of a split-phase motor mounted on the shaft of a two-cylinder single acting compressor. These oscillating cylinders, together with the eccentric which drives them, are of the same general design as those which have performed so successfully in the

Audiffren machines. Those parts and an expansion valve are enclosed in a hermetically sealed bronze case which rests on top of the refrigerator box. This case supports the condenser coil surrounding it and the evaporator coils hanging into the brine tank in the box below. The brine tank is not directly attached to the machine but is supported from a flange which fits into a recess in the lid of the box.

The motor used in the present design is of very simple construction, split phase with no moving parts except a squirrel cage rotor. Current is brought into the case through special glass insulated leads developed by the research laboratory for this purpose. Having eliminated from the motor all centrifugal switches, brushes and other complications, the control panel is equipped with a current limit relay to throw over from starting to running position. It also includes a thermostatic switch to start and stop the machine in response to brine temperature changes, and a time limit overload relay to protect the motor. This control panel is enclosed in a sheet metal box supported on the machine, which box will be normally sealed closed though it may be opened for adjustment. By means of a tumbler switch on the side of the box, the machine may be shut down if desired. The machine has no external moving parts, such as motor, belt, fly wheel or fan and is therefore free from the danger attending the operation of many other machines. The simple exterior together with the white pyralin finish presents a very attractive appearance.

The box is substantially built with white oak exterior and white vitreous enamel sheet steel lining. The heavy hardware and

gaskets around the doors prevent leakage. The insulation consists of two inches of cork. The outside dimensions of the box are,

Width 41"

Height 53"

Depth 25"

The total inside volume is approximately 14 cu. Ft. of which approximately 9 cubic feet is available for food storage. The steel brine tank is finished in vitreous enamel and sufficient space is provided between it and the box to permit of easy access for thorough cleaning. This box in the quality and quantity of insulation, its sturdiness of construction and the ease with which it may be cleaned is superior to any other box on the market. Special precautions have been taken to seal all the interior woodwork, thus preventing musty odors frequently found in other refrigerators. It is made to our designs by one of the largest manufacturers in this line.

INSTALLATION

The outstanding advantage of this machine is that it will be charged at the factory with gas and oil, sealed up and together with the refrigerator box and brine tank, shipped in three parts ready for installation. In one half hour two men can easily roll the box into place, drop in the brine tank, fill it with brine and place the machine on top of the box with the expansion coils hanging in the brine. To start the machine it is then necessary only to connect into an outlet or lamp socket. No adjustments nor tests will ordinarily be required on the customers' premises.

Contrast the simplicity and low cost of this installation with

the preliminary survey, piping and connecting required by many other systems of domestic refrigeration

SERVICE

In case of complaint minor adjustments in our control mechanism can be made on the customer's premises.

The mechanism inside the main case is so simple and rugged there is little likelihood of failure. In case of trouble, however the machine would be replaced in about fifteen minutes work on the customer's premises and taken to a service station or sent to the factory for examination and repair. Since no major repairs would be attempted on the customer's premises, the service man would require only a little knowledge of electrical control apparatus. It is said our competitors can make repairs on the spot. They can service the motor, replace the belt, oil some of the exposed bearings, tighten the stuffing box and gas to replace what has leaked through stuffing box and pipe connections. It is our understanding, however, that major repairs, such as replacement of valves, taking up bearings, etc. are made in a service shop.

To remove one of those competing machines involves the opening of the pipe lines, with loss of some gas, and the danger of getting air and moisture into the system. Our own machine, being self-contained is simply lifted out of the brine tank and the box without breaking pipe connection. To facilitate this operation of insulation and removal we have developed a convenient crane which can be collapsed ready transportation. It is obvious that the kind of service our competitors do on the spot will not be necessary with our machine with

possible exception of control adjustments. We had no belt to replace. No external bearings to lubricate, no brushes, centrifugal switches, etc. to adjust on the motor, and no danger of gas or oil leakage, since our machine has no stuffing box and is hermetically sealed, all joints being thoroughly soldered in the factory.

RELIABILITY

The above discussion under “SERVICE” enumerates the reasons for our faith in the reliability of this machine, which can be summed up as follows:-

All operating parts are completely sealed with a supply of lubricant adequate for all time, and there is no stuffing box to leak either gas or oil.

The motor is very simple, without brushes, short circuiting switches or moving contacts.

The machine is charged and sealed at the factory under ideal conditions for excluding moisture and air and does not require any piping or gas connections on the customer’s premises.

The eccentric driven single-acting oscillating cylinder compressor with snifter discharge valves, all essentially as used in the Audiffren machine for so many years, is the simplest and most reliable form of compressor of which we have knowledge.

The use of materials and methods of lubrication, peculiarly adapted to this machine, developed by long experience with the Audiffren and later designs.

PROTECTION

Patent approval on this design was obtained some time ago, and the applications are pending covering certain details. However, the broad ideas are old and we will have no valuable patent protection. Nevertheless the experience gained in building the Audiffren machine and in developing the domestic device constitutes a broad knowledge of the art, which is highly essential to successful production, and which would require considerable time and expense for others to acquire.

CAPACITY AND ECONOMY

The following data are compiled from careful tests made in our own factory upon various machines.

Capacity	<u>Room Temp. 75°F</u>		<u>Room Temp. 90°F</u>	
	Economy	Capacity	Economy	
	Watt-hr B.t.u.	B.t.u. per hr.	Watt-hr B.t.u.	B.t.u. per hr.
OC-2	0.387	650	0.500	510
Odin	0.41	630	-	-
Savage Arms	0.58	570	0.71	430
Kelvinator 1 Cyl.	0.835	370	0.90	350
Model #1420 “ 2 “	0.515	685	-	-
Frigidaire 2 “	0.517	710	0.598	620
SerV-el 2 “	0.374	928	0.484	739

These tests indicate performance of the machines alone on a test brine tank and do not include the characteristics of the box. ? rate of 600 B.t.u. per hour is equivalent to the melting of 100 pounds of ice in 24 hours.

This table indicates that our machine takes less power per unit of refrigeration than any other, except the SerV-el, which is about 3% more efficient at 75°F. room temperature. That is probably due to the larger capacity of the SerV-el machine, it being a well known fact that other things being equal the larger the machine the higher the efficiency. The power input on our machine is about 250 watts against 350 watts for the SerV-el.

We have built one model of about the same size as the SerV-el which showed an economy of .323 W. Hr. per B.t.u., which is about 14% higher efficiency than the SerV-el.

We consider our machine is of a capacity best adapted to the box we are furnishing, since it will maintain proper temperatures even on a 90°F. day with 11 hours operation in each 24 hours.

SerV-el is sold for use with boxes already in service, many of which have poor insulating qualities and therefore require more refrigeration.

ENERGY CONSUMED

Aside from the efficiency of the machine, the cost of operation is dependent upon the quality of the box and its resistance to the leakage of heat. For this reason operating tests of different machines are not comparable because of the wide variation in box efficiency.

Mr. T. I. Jones of the Brooklyn Edison Co. in a paper presented before the Association of Edison Ill'g. Companies, Oct. 1922, gave an annual current consumption of 800 K.W. hours for these machines, which is at the rate of 2.19 K.W.H. per day the year around.

One of our machines with standard box in Mr. H. E. Crane's

home consumed in actual operation an average of 2.6 K.W.H. per day for sixty-hour days from July 25 to Sept. 28, 1924. This was a period of unusually high temperature with several days of 93°F., or over. From Sept. 28, 1924 to Feb. 12, 1925, a period of 137 days, the consumption has averaged 2.36 K.W.Hr. per day. The average for the total 201 days is 2.44 K.W.Hr. per day.

DEVELOPMENT

Applied apparatus expense expenditures totaled \$54,217.00 up to Dec. 31, 1924. The engineering budget submitted recently contained an item of \$46,110.00 A.A.E. for this work for 1925. This, of course, is an estimate only. Future development will be directed along lines indicated by experience with the present machine, and as dictated by the trend of commercial requirements. Tools and patterns for various rates of production must be provided at the estimated costs.

100 machines	\$8,000.
Additional for 1000 “	5,000
“ “ 3000 “	<u>5,000</u>
Total for - - - 3000 “	\$18,000

COSTS

Estimates just completed show costs on the machine complete including control panel and brine tank, but not including the box, as follows:-

	<u>LOTS</u>	<u>100</u>	<u>1000</u>	<u>3000</u>
Material		78	77.75	75.98
Direct Labor		60	29.67	26.64
Expense (150%)		<u>90 (135%)</u>	<u>40.47 (120%)</u>	<u>31.97</u>
		220	147.47	134.59

On boxes we have a firm quotation of \$115.00 in lots of 100 F.O.B. St. Paul, and estimate a price of \$100.00 in lots of 1000 or 3000.

Realizing there are many methods of determining a price, we Merely suggest the following items which might be included.

PRICES

BASED ON A PRODUCTION OF 3000 PER YEAR

Machine complete	-	-	-	-	\$ 135.00
A.A.E. 25%	-	-	-	-	<u>33.75</u>
Gross Factory Cost	-	-	-	-	168.75
Commercial Expense - 16 2/3%					28.12
					<u>196.87</u>
Profit 20%	-	-	-	-	246.10
Crating					<u>4.00</u>
					250.10
Refrigerator Box F.O.B. St. Paul					100.00
Handling charge 10%					10.00
Freight St. Paul to Ft. Wayne					<u>1.92</u>
Price to agent FOB Ft. Wayne					362.02
Discount to agent to cover freight, installation charge and profit 34% of \$550.00					187.00
Selling price to customer -					\$ 549.00

This set up is made merely as a suggestion and will no doubt be materially modified by any commercial organization undertaking the sale of this device. However, it indicates that the total development incurred up to this date can be liquidated in the sale of 3000 machines a commercial selling expense provided for which is in all probability more than ample for this class of appliances a satisfactory profit for the G.E. Co. and a working discount or commission for the distributor.

COMPARISON WITH PRICES OF OTHER MACHINES

The following prices are delivered and installed, including box

	<u>Cu. Ft.</u>	<u>Price</u>
OC-2	9	\$ 550.00
Frigidaire	9	605.00
SerV-el	9	550.00

	<u>Cu. Ft.</u> <u>Food Space</u>	<u>Price</u>
Kelvinator) machine) \$340.00 installed)		
Box brought) retail equal) 200.00 to ours)	9	\$540.00

PROGRAM

Our definite recommendation is to begin the manufacture as soon as authority can be secured (not later than March 1st, 1925) of 100 machines and the purchase of 100 boxes, these equipments to be sold in Fort Wayne and one other nearby city, preferably Cincinnati or Cleveland, where sales and service efforts can be concentrated and carried on at a minimum of expense. This will involve the purchase of materials, the making of patterns and tools and the training of help. If authority can be secured by March 1st, we can start assembly June 1st, at the rate of five per week, and complete assembly of 100 machines by September 1st.

The sale and servicing of these first 100 machines can be handled by the factory organization here at Fort Wayne with some slight sales assistance from the local office. Following is an estimate of the cost of this program.

100 refrigerating machines at \$230.00 -	\$23,000.	
100 refrigerator boxes, FOB		
St. Paul, Minn. - - -	115.00 -	11,500
Boxing refrigerator machines	<u>500</u>	
Shop cost- boxed- - - - -	-	\$35,000.00
Freight on boxes - - - - -	500.	
Freight on refrigerating machines- - - - -	200.	
Cartage and installation - - - - -	1,500.	
Sales expense, salaries, rental, show space and servicing six months Cincinnati or Cleveland	5,000.	
Selling and servicing Fort Wayne	1,000.	
Extra traveling expenses- - - - -	600.	
Local advertising and bulletin- - - - -	1,000.	
Contingencies and complaints - - - - -	<u>5,200.</u>	
Total sales and distribution expense - - - - -		15,000.00
Re-arrangement manufacturing facilities	2,000.	
Tools and patterns for 100 machines- -	<u>8,000.</u>	<u>10,000.00</u>
GRAND TOTAL		\$60,000.00

At a selling price of \$550.00 this initial campaign would show only a small loss and would give us a very valuable and necessary experience.

Upon the completion of this program we will be in an excellent position to go ahead with a production of 1000 machines in 1926 and further extensions in the future, provided the commercial department has developed an adequate plan for the sale of this product.

CONCLUSION

Based upon many years experience in the manufacture of the Audiffren and in the development of this domestic machine, supplemented by tests on all the leading domestic machines now on the market, we are convinced that the present machine is superior to any now on the market

While no doubt improvements will continue to be made in the present design, we feel sure we should undertake immediately to exploit this machine. To keep pace with the development in this new industry on which so much time and money are being spent by our competitors, we must continue our development work aggressively.

Ed note: supplement included 9 photos and drawings that were too dark to copy. Original copies of the GE photos are in the GE Photo Collection at the Schenectady Museum

GE photo# 283076 "OC-2, Form H Refrigerating Machine on Seeger #370 Special Refrigerator

GE photo# 283077 "OC-2, Form H Refrigerating Machine on Seeger #370 Special Refrigerator

GE photo# 283079 "OC-2, Form H Refrigerating Machine removed from Seeger #370 Special Refrigerator, door open showing brine tank in place.

Drawing (no number or title) Ed note: shows crosssection of OC-2 evaporator

Photo (no number or title) Ed note: shows open control box for OC-2

Photo (no number or title) Ed note: shows outside of control box for OC-2

Drawing (no number or title) Ed note: shows crosssection of OC-2 compressor and condenser

Illustration (no number or title) Ed note: shows remotely installed Kelvinator system

Illustration (no number or title) Ed note: shows remotely installed Frigidaire system

APPENDIX #1

Editor's Note: This is one page, faded so that it is virtually unreadable. It appears to be a table of data on the Audiffren machines from 1917 – 1921.

APPENDIX #2.

EXPENSES ALREADY INCURRED FOR DEVELOPMENT

Schenectady, July 2, 1923.

Mr. A. B. Stevenson, Jr.,
P & M Engineering Dept.,
B U I L D I N G.

Attached is a detailed statement covering Applied Apparatus Expenditures on Refrigeration Work done at the Schenectady, Lynn, Pittsfield and Ft. Wayne Works since 1915. This report indicates that the Company has spent since 1915 an aggregate of \$138,733. for the development of domestic and Audiffren machines. During this period, \$99,149. of the above development was written off: \$13,873. was transferred to the General Office, and \$11,555. was credited to the several accounts from credits received through shipments. This has resulted in an unliquidated balance on June 1, 1923 of \$14,156.

I believe the above gives you the information requested in your recent letter.

Yours truly,
N.J. KINGSBURY.
For: A. W. Oppermann

AWO:W

RECAPITULATION OF APPLIED APPARATUS EXPENDITURES

TO JUNE, 1 1923 ON REFRIGERATION WORK

(Does not include development on Audiffren machines.)

				<u>TOTAL EXPENDITURES</u>
Schenectady Works	-	-	- \$ 2,490.	No work now being done.
Lynn Works	-	-	- 15,945.	“ “ “ “
Pittsfield Works	-	-	- 832.	“ “ “ “
Fort Wayne Works	-	-	- 87,226	Work actively going on.
TOTAL EXPENDITURES			<u>\$106,493</u>	
Written off or charged to residue	-	-	- 99,149	
Unliquidated balance in Dev, a/c June 1, 1923			<u>\$ 7,344</u>	

DEVELOPMENT WORK ON REFRIGERATION

SCHENECTADY RESEARCH LABORATORY

<u>Year</u>	<u>Research Laboratory</u>	
1915	\$ 936.	Written off in December, 1915.
1916	738.	\$540. written off in Dec. 1917 (Bal. Charged to residue)
1917	---	
1918	---	
1919	478.	Charged to residue.
1920	318.	" " "
TOTALS	<u>2,490.</u>	

LYNN WORKS

<u>Year</u>	<u>Debits</u>	<u>Credits</u>	<u>Written off</u>	<u>Unliq. Balance Accumulative</u>
1919	\$ 3,025.	---	-----	\$ 3,025.
1920	8,858.	---	-----	11,883.
1921	4,062.	---	-----	-----
TOTAL	<u>\$15,945.</u>	---	<u>\$ 15,945.</u>	-----

FORT WAYNE WORKS

DOMESTIC ICE MACHINES

DEV. a/c 98

<u>Year</u>	<u>Debits</u>	<u>Credits</u>	<u>Written off</u>	<u>Unliq. Balance (Accumulative)</u>
1918	\$ 3,166.	---	---	\$ 3,166.
1919	19,725.	---	---	22,891.
1920	17,305.	---	---	40,196.
1921	21,566.	---	---	61,762.
1922	18,120.	---	\$ 79,882.	---
1923 (5 mos.)	7,344.	---	---	7,344.
<hr/>				
TOTAL	\$87,226.	---	\$ 79,882.	\$ 7,344. (6/1/23)

PITTSFIELD WORKS

Development work done by Mr. W. Stanley at the Gt. Barrington
Laboratory. This work was charged to the General Office - - - \$832. - - -

RECAPULATION OF APPLIED APPARATUS EXPENDITURES
TO JUNE 1, 1923 ON AUDIFFREN REFRIGERATING MACHINE

Expenditures from 1916 to June 1, 1923	-	-	-	- \$ 32,240.
Debits transferred to General Office	-	-	-	- 15,062.
Balance	-	-	-	<u>- \$ 17,178.</u>
Credits received thru shipments	-	-	\$ 11,555.	
Credits transferred to G.O.	-	-	1,189.	<u>\$ 10,366.</u>
Unliquidated balance in Dev. a/c June 1, 1923	-	-	-	- \$ 6,812.
Work is natively going on.				

FORT WAYNE WORKS

AUDIFFREN REFRIGERATING MACHINE

Dev. a/c 99

<u>Year</u>	<u>Debits</u>		<u>Credits</u>		<u>Unliquidated Balance Accumulative</u>
	<u>Expds.</u>	<u>Trans. to G.O.</u>	<u>Liquidations thru Shipments</u>	<u>Trans. to G.O.</u>	
1916	\$ 22.	---	---	---	\$ 22.
1917	2120.	---	---	---	2142.
1918	3953.	\$ 5670.	\$ 871.	\$ 1579.	1133.
1919	3439.	4495.	390.	390.	77.
1920	5158.	4897.	---	---	338.
1921	6136.	---	5404.	---	1070.
1922	7546.	---	3933.	---	4683.
1923 (5 mo.)	3866.	---	1737.	---	6812.
TOTAL	<u>\$32,240.</u>	<u>\$15,062.</u>	<u>\$11,555.</u>	<u>\$1,189.</u>	<u>\$6,812</u> (6/1/23)

APPENDIX 3

The following table, quoted from Mr. T. I. Jones' paper, read October 1922 before the Association of Edison Illuminating Companies, shows a comparison of the revenue derived from household electrical appliances. Mr. Jones states that the KW hours used are based upon a record of actual use. If a special 5 cent rate, as has been suggested from some sources, were made for refrigeration business, this would reduce the revenue figure shown in the table from \$64.00 to \$40.00

	Maximum Demand <u>Watts</u>	Annual <u>kw-hr.</u>	Annual <u>Rate</u>	Annual <u>Revenue</u>	Annual Rev. per kw of <u>demands</u>
Waffle irons	600	30	\$0.08	\$2.40	\$4.00
Grills	500	34	0.08	2.72	5.64
Heaters (radiant)	600	42	0.08	3.36	5.60
Toasters	500	37	0.08	2.96	5.92
Washing Machines	300	26	0.08	2.00	6.67
Percolators	400	42	0.08	3.36	8.40
Irons	600	72	0.08	5.76	9.60
Ironers (electrically heated)	3000	360	0.08	28.80	9.60
Vacuum cleaners	800	87	0.08	2.16	10.80
Radiators	600	96	0.08	7.68	12.80
Ironers (gas heated)	300	60	0.08	4.80	16.00
Heating pads	50	15	0.08	1.20	34.00
Fans	50	16	0.08	1.28	25.60
Sewing machines	50	17	0.08	1.36	27.20
Lamps (portable)	150	60	0.08	4.80	32.00
Ranges	2500	1500	0.08	120.00	48.00
Refrigerators	300	800	0.08	64.00	213.33

APPENDIX 4

TABLE COPIED FROM ICE & REFRIGERATION BLUE BOOK

The consumption of ice in tons for commercial purposes by states is estimated at 35,305,000 tons. By the term commercial is meant ice sold to families, butchers, stores of various kinds, etc., and does not include ice used for cold storage purposes and ice manufactured by plants using it for their own purposes. The approximate amount consumed in each state from figures obtained from various sources, is shown in table XII.

TABLE XII – Estimated Consumption Of Ice In Various States

State	Annual Consumption (Tons)
Alabama	380,000
Arizona	245,000
Arkansas	500,000
California	1,500,000
Colorado	360,000
Connecticut	300,000
Delaware	150,000
Florida	650,000
Georgia	750,000
Idaho, Montana, NewMexico, Utah, and Wyoming	150,000
Illinois	3,500,000
Indiana	1,200,000
Iowa	450,000
Kansas	600,000
Kentucky	525,000
Louisiana	750,000
Maine	150,000
Maryland	625,000
Massachusetts	1,000,000
Michigan	600,000
Minnesota	400,000
Mississippi	250,000
Missouri	2,000,000
Nebraska	300,000
Nevada	50,000
New Hampshire	100,000
New Jersey	1,250,000
New York	5,000,000
North Carolina	385,000
The Dakotas	130,000
Ohio	2,000,000
Oklahoma	325,000

Oregon	90,000
Pennsylvania	5,250,000
Rhode Island	525,000
South Carolina	300,000
Tennessee	525,000
Texas	2,000,000
Vermont	60,000
Virginia	650,000
Washington	200,000
West Virginia	275,000
Wisconsin	300,000
District of Columbia	225,000
<hr/>	
Total	35,385,000
<hr/>	
<hr/>	

It is a well-known fact to those engaged in the ice business that it is a seasonal one. This is also known in a general way by the public, but to just what extent is the percentage of sales monthly to total sales is not, known, and it is doubtful if the majority of men engaged in the industry fully realize that fact also. More than 70 percent of the total sales for the year are made in the period from May to September. Table XIII shows the average percentage of sales of ice by months, compiled from figures obtained from 160 cities and towns throughout the United States.

TABLE XIII – Average Percentage Of Sales Of Ice By Months

Month	Percentage of Sales	Month	Percentage of Sales
<hr/>			
January	2.6%	September	14.4%
February	3.0	October	8.2
March	3.8	November	3.6
April	6.5	December	<u>2.7</u>
May	9.6		
June	13.5		
July	17.0		
August	18.8		

TABLE SHOWING AVERAGE RETAIL PRICES
 CHARGED FOR ICE IN VARIOUS SECTIONS
 OF THE UNITED STATES

District				Retail Price In Cents Per <u>Hundredweight During Year</u>	
				1922 x	1923 o
Eastern-	-	-	-	59.1 cents	62.3 cents
Midwestern	-	-	-	59.2	60.7
Western	-	-	-	73.5	83.0
Southern	-	-	-	60.1	61.7
General Average	-	-		62.3	65.0

x from Ice & Refrigeration Blue Book

o From page 451 May 1923 Ice and Refrigeration magazine.

TABLULATION OF ICE DELIVERY COSTS IN NEW YORK CITY
 COPIED FOM PAGE 12 OF THE SEPTEMBER 1921
 REFRIGERATING WORLD.

Weight of Unit Delivered	Minimum Cost of Delivery	Maximum Cost of Delivery
15 lbs.	7.74 (a)	17.25 (b)
25 lbs.	9.25 (a)	23.6 (c)
50 lbs.	12.96 (a)	34.3 (c)
75 lbs.	16.95 (a)	41.50 (c)
100 lbs.	20.05 (a)	47.20 (c)

- (a) Driver does not enter house but drops ice at curb in accordance with standing order on card in window.
- (b) Driver enters house, goes up half a flight of stairs and examines box, goes back to wagon and carries ice up.
- (c) Apartment house. Driver inquires up the dumbwaiters, sends ice up dumbwaiter and goes up himself to lift ice out of dumbwaiter into ice box.

APPENDIX #5
 Replies From Superintendents of Water Works
 In Texas, Georgia, and New York State.

Temperature of Water In The Hottest Part of Summer

<u>Texas</u>	<u>Temperature</u>	<u>Price</u>
Dallas	90 degrees Fahr.	?
Amarillo	87 deg. Fahr.	75 cents per 1000 cu. Ft.
Fort Arthur	70 deg. Fahr.	30 cents “ “ gallons
Sherman	60 deg. Fahr.	?
Texarkana	85 deg. Fahr.	1 st 13,500 gals – 50 cents per M Next 48,000 gals – 40 cents per M Next 60,000 gals – 30 cents per M Over 121,000 gals – 20 cents per M Minimum charge per quarter - \$3.75
Ranger	70 deg. Fahr.	?
 <u>Georgia</u>		
Atlanta	Between 75 cents & 90 cents	Within city limits – 10 cents per M Out side city limits – 20 cents “ “
Lagrange	?	? Prefer air cooled machines.
Augusta	?	1 st 1000 gals per day –25 cents M Next 19000 gals per day –20 cents M Next 10000 gals per day –15 cents M Over 30000 gals per day – 12.5 cents M
Athens	72 deg. Fahr.	10 cents to 25 cents per M gals.
 <u>New York</u>		
Gloversville	?	Minimum charge per 6 months \$2.00 1 st 5000 cu. Ft. – 12 cents per 100 Next 5000 cu. Ft. – 10 cents per 100 Next 5000 cu. Ft. – 8 cents per 100 Next 5000 cu. Ft. – 6 cents per 100 Next 5000 cu. Ft. – 4 cents per 100 Over 25000 cu. Ft. – 3.5 cents per 100

<u>New York</u>	<u>Temperature</u>	<u>Price</u>
Corning	45 deg. Fahr.	Not any
Niagara Falls	22 deg. Cent.	Less than 20000 cu. Ft. – 8 cents per 100 20000 to 40000 cu. Ft. – 7 cents per 100 40000 to 60000 cu. Ft. – 6.5 cents per 100 60000 to 80000 cu. Ft. – 5.5 cents per 100 80000 to 100000 cu. Ft. – 4.5 cents per 100 100000 to 250000 cu. Ft. – 4 cents per 100 Over 250,000 cu. Ft. – 3 cents per 100 (per quarter) Min. rate \$6.00 per year.
Syracuse	58 deg. to 70 deg. Fahr.	?
New Rochelle	70 deg. Fahr.	1 st 20,000 cu. Ft. – 30 cents per 100 cu. Ft. Next 20,000 cu. Ft. – 27 cents per 100 cu. Ft. Next 20,000 cu. Ft. – 25 cents per 100 cu. Ft. Next 20,000 cu. Ft. – 22.5 cents per 100 cu. Ft. Over 80,000 cu. Ft. – 20 cents per 100 cu. Ft.
Lockport	60 deg. to 65 deg. Fahr.	10 cents per 1000 gallons
Rome	?	Not any
Schenectady	59 deg. Fahr.	1 st 10,000 cu. ft.- 5 cents per 100 cu. ft. Over 10,000 cu. ft- 4 cents per 100 cu. Ft. (six months)
Rochester	70 deg. Fahr.	?
Jamestown	50 deg. Fahr.	20 cents per 100 cu. ft. Minimum charge - \$1.50 per motor
Oswego	65 deg. to 70 deg. Fahr.	25 cents per 1000 cu. ft.
Geneva	62 deg. Fahr.	1 st 1300 cu. ft.- 25 cents per 100 cu. ft. 1300 to 14300 “ “ – 13 cents per 100 Over 14,300 “ “ – 6 cents per 100 Minimum motor rate - \$2.00

Elmira	58 deg. in May	1 st 1300 cu. ft.- 30 cents per 100 cu. ft. Next 1300 cu. ft.- 26.18 cents per 100 Next 1400 cu. ft.- 22.44 cents per 100 Next 5400 cu. ft.- 15 cents per 100 100000 cu. ft.- 7.5 cents per 100 200000 cu. ft.- 7 cents per 100 Balance - 6 cents
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<u>New York</u>	<u>Temperature</u>	<u>Price</u>
Olean	From wells 45 deg. to 50 deg. F. From creek 75 deg. to 80 deg. F.	?
Ogdensburg	68 deg. Fahr.	10 cents per 1000 gals.
Watertown	Same as ground	?
Yonkers	60 deg. Fahr.	16 cents per 100 cu. ft.
Mount Vernon	75 deg. Fahr.	1 st 1500 cu. ft.- 32 cents per 100 cu. ft. Next 45000 cu. ft.- 26 cents Next 50000 cu. ft.- 20 cents Over 100000 cu. ft.- 15 cents (within quarter)
Kingston	?	1 st 1500 cu. ft.- 2.50 Next 3500 cu. ft.- 1.500 per M cu. ft. Next 5000 cu. ft.- 1.00 `` `` `` `` Next 10000 cu. ft.- 70 cents `` `` `` `` Next 20000 cu. ft.- 50 cents `` `` `` `` Minimum motor rater per quarter \$3.50
Poughkeepsie	60 deg. Fahr.	1 st 10000 cu. ft.- 2.00 per M cu. ft. Next 10000 cu. ft.- 1.75 `` `` `` `` Over 20000 cu. ft.- 1.60 `` `` `` ``
Glens Falls	?	?
Amsterdam	?	1 st 40000 cu. ft.- 8 cents per 100 cu. ft. Next 100000 cu. ft.- 5 cents per 100 Over 140000 cu. ft.- 3 cents per 100 (by quarter)

Buffalo	60 deg. to 65 deg. Fahr.	Not any
Ithaca	?	Rates vary from 70 cents per M cu. ft. to \$3.50 per M cu. ft. and it will be necessary to refer to Rate Book.
Peekskill	?	16 cents per 100 cu. ft.
Laskawasso		Same as Buffalo
Hornell	?	?
New York City	73 deg. Fahr.	\$20 per ton per year for the actual capacity of machine, where rated ton capacity is less than one ton, a charge is made in accordance with the fractional part of a ton, with a minimum charge of \$5. per ???.

APPENDIX #6

ICE BOXES

AVERAGE BOX

1. Test Data

Mr. Alder of the Good Housekeeping Institute made some tests on standard ice boxes to determine the amount of ice meltage and food compartment temperatures. The boxes tested were as follows: -

Rating in Lbs. of ice	Volume of ice compartment cu. ft.	Volume of food compartment cu. ft.	Total Internal Volume
125	2.94	5.93	8.87
109	2.2	6.06	8.25
90	2.04	4.97	6.91

Mr. Alder was not at liberty to tell me the names of the manufacturers of those boxes, but said they were of good commercial quality, being sold at from \$70.00 to \$100.00. He believed they would have about a ten year life.

Mr. Alder made several 100 hour tests on these ice boxes during which the ice was replaced up to the full capacity of the box every twenty-four hours. He found that the ice meltage was about .007 lbs. of ice per hour, per cubic foot of food compartment volume, per

degree difference in average food compartment and room temperatures.

Room Temperature	Temperature in Food Compartment	
71.7 degrees	46.7 degrees	
80	51	
90	58	

There seems to be a general impression that humidity has a great effect upon the heat radiated from an ice box. Both Mr. Doherty and Mr. C. W. Rice, who have made extensive studies of the convection and radiation of heat, assure me that the humidity can be neglected. Its effect is negligible unless water is actually sprayed on the surface and allowed to evaporate.

This is confirmed by paragraph four, page 56, of Bulletin No. 102 of the University of Illinois, "A Study of the Heat Transmission of Building Materials". It is also confirmed on page 65, of Bulletin No. 9 of the Pennsylvania State College.

However, our Fort Wayne engineers point out that if the air is so damp that the two or three degrees lower temperature of the outside of the box causes water vapor to condense, there will be a distinct effect. I do not know of any tests to show this, and the calculation of

the rate of condensation would be very complicated. Therefore, I will neglect the effect of humidity. This simplifies the problem considerably.

The Bureau of Standards has made an investigation of domestic refrigerators, the results of which are give on pages 51, 52, and 53, of Bulletin No. 55, issued August 28, 1915. Table No. 2 from this report is quoted below for comparison with Mr. Alder's figures. It will be noticed that the coefficient of heat transmission per hour, in B.t.u., per square feet, per degree Fahrenheit temperature difference, varies from .14 to .21; whereas, Mr. Alder's figures have a c coefficient of .143. This would indicate that the boxes tested by Mr. Alder are above the average quality.

Refrigerator Number	Room Temperature	Coldest Inside Temperature	Warmest Inside Temperature	Weight of Ice melted per hour	Heat Transmission per hour	Air circulation	Inside volume	Average weight of ice in box during test	
	Degrees Fahrenheit	Deg. Fahr	Deg. Fahr	Lbs.	Btu per sq. ft. per Deg. Fahr. Temp. diff.	Cu. ft. per minute at 60 deg. Fahr.	Cu. Ft.	Lbs.	
1	92.1	52.7	64.4	1.5	0.14	21.4	16.5	42.2	
2	91.8	57.2	72.1	1.78	0.21	19.6	18.1	37.1	
3	91.3	49.3	70.7	1.63	0.19	12.7	18	41.1	
4	90	46.6	70.3	1.43	0.14	10.1	18	43.2	
5	89.6	49.5	68.7	1.41	0.15	12.1	16.5	41.2	
6	91.1	55.9	69.8	1.51	0.18	18.5	18.2	42.7	
7	91.5	46.9	66.2	1.63	0.15	13.8	17.1	41.8	
8	92	44.1	64	1.59	0.14	13	17.3	41.7	
9	93.1	51.8	66.6	1.65	0.19	18.5	19	40.7	

I wrote to eighty-one manufactures of ice boxes asking for scientific data and only eight were able to give intelligent replies.

There is a special appendix on the ice box manufactured by the American Balsa Company, which I believe to be the best box on the market from both the standpoint of efficiency and cost.

2. Analysis of Operation with Ice

a. The first three lines of the following table are obtained directly from Mr. Alder's figures for the on hundred pound box.

TABLE #

	Ice Metage Lbs. Per Hour	Temp of Ice	Diff. In Temp	Temp. of Food	Diff in Temp	Room Temp	Type of Insulations	Insulated Area in Sq. Ft.	B.t.u. per sq. ft., per hour, per degree
1	1.06 #	32 deg.	14.7 deg.	46.7 deg.	25 deg.	71.7 deg.	Standard	42.5	0.143
2	1.23	32	19	51	29	80	Standard	42.5	0.143
3	1.36	32	26	58	32	90	Standard	42.5	0.143
4	1.28	20	20	40	30	70	Standard	42.5	0.143
5	2.12	-9	49	40	50	90	Standard	42.5	0.143
6	0.8	32	8	40	30	70	1 inch additional cork	42.5	0.0905
7	1.12	32	16	48	42	90	1 inch additional cork	42.5	0.0905
8	0.8	32	8	40	50	90	3 inch additional cork	42.5	0.054
9	0.55	32	2.5	34.5	35.5	70	3 inch additional cork	42.5	0.054

Foot-note (-): The outside dimensions of the box are assumed 46`` high, 32.5`` wide, 19.5`` deep.

Foot-note (#): These temperatures are assumed to be obtained by the use of ordinary salt or calcium chloride crystals.

b. It will be noted that Mr. Alder's figures assume that the heat transmission through the box insulation is a linear function of the temperature drop between the outside air and the food compartment. This is theoretically correct if the contact resistance Between the air and the box can be neglected.

c. Mr. C. W. Rice has given me a formula for the contact resistance to the flow of heat from a cylinder. This formula is for convection only. Mr. Rice's formula shows that although the contact resistance cannot be neglected, it can be considered as practically a linear function within the range of temperatures under discussion.

Foot-note (#): Mr. Rice will read a paper, "Free and Forced Convection of Heat in Gases and Liquids", at the June, 1923, A.I.E.E Convention.

Other papers on the laws of Heat and Transmission are:

1. Laws of Heat Transmission in
Electrical Machinery
I. Langmuir
A.I.E.E. Feb., 1913.

2. Convection and Radiation of Heat
I. Langmuir
American Electrochem Society
Vol. XXIII, Pge. 299-332
April, 1913.

3. Convection and Conduction of Heat in Gases
Physical Review – 1912.

4. Thermal Condensation and Convection in
Gases at High Temperatures.
Transaction from American Electrochem
Society – 1911.

On page 40 of the University of Illinois Bulletin NO. 102, a formula is given for the contact resistance, from which a temperature difference of 2.6 F could be calculated. This is 23.3 percent less than Mr. Rice's formula. I should not expect a much closer check than this.

About the same drop could be calculated from the inside of the box to the air in the food compartment. This makes a total contact drop of 6.4 degrees F. The total drop was 25 degrees: therefore, the drop through the insulation must have been about 18.6 degrees. The insulation was apparently equivalent to 1 1/3 inches of cork.

In general, it will be noted that in the range of temperatures under consideration the contact resistance can be considered linear, and, therefore, lumped with the insulation resistance.

d. An analysis shows that at least within the range of Mr. Alder's tests, the rise in temperature between the ice and the center of the food compartment has a variation which is proportional to the convection between two chambers at these temperatures.

- e. The attached maps of the climate show
(Editors note: faded beyond recognition)

the temperatures which will be encountered all over the
United States.

I have decided it would be unreasonable
to design the boxes for the extreme temperature of 110 degrees,
but believe that the box should be suitable for use in
room temperatures up to 90 degrees F.

Dr. John R. Williams, Secretary of the
Milk Commission, Rochester, New York, in a paper before the
Third International Congress of Refrigeration, in 1913,
states:

(EDITORS NOTE: remaining pages are missing)

January 17, 1924

APPENDIX # 6-A

REFRIGERATOR SUGGESTED BY Mr. A. L. GIVENS

Mr. Givens has suggested a new principle of refrigerator, which system might be termed a "prevention" rather than a "cure". In previous practice, the heat has been allowed to leak into the refrigerator through insulation, and has then been removed from the refrigerator by air convection to a brine tank. Mr. Givens suggests that the cooling unit, either brine tank or trays containing melting ice, be connected directly to the sheet metal, enameled lining of the refrigerator. Any heat leaking through the cork insulation would be caught on the sheet metal lining and conducted directly to the cooling unit. Mr. Givens has suggested that the cooling unit might be mounted in the center of the box.

The enameled sheet steel linings of refrigerators, I understand, are usually 1/16" thick. It would probably be advisable in making a refrigerator along the lines of Mr. Givens' suggestion to use at least 1/8" steel, in which case the lining should not rise higher than 49.4°F., at the point farthest from the refrigerating unit. In these calculations, it has been assumed that any heat which leaks in through the door of the refrigerator will be convected through the interior air to the wall of the food compartment which is next the cooling unit.

This construction has the great advantage that each food compartment will be complete in itself, the porcelain

lining having rounded corners which can easily be cleaned. None of the oil vapors from the food will be carried over the ice trays, as in the Savage Arms design. It will, therefore, be unnecessary to clean the ice trays or the brine tank, if a brine tank should be used.

APPENDIX #7

DISCUSSION OF THE FACTORS
WHICH INFLUENCE THE RATING OF A
DOMESTIC REFRIGERATING MACHINE.

1. The table on page 5 of appendix #6 shows that to maintain a temperature of 40° in a standard hundred pound ice box with a room temperature of 90°, would require a brine tank temperature of -9°F. and a rate of ice meltage of about 2.12 lbs. of ice per hour.

On account of the danger of freezing up the oil, it would probably be inadvisable with most types of refrigerating machines to attempt to carry the brine at a temperature lower than plus 20°F.

With the brine tank at 20°F. on a 90° day, the food compartment would be about 52 ½° and the rate of ice meltage would be 1.6 lbs. per hour.

Therefore, unless the refrigerating machine is of a type which can be operated with a brine tank temperature of less than 20°, it would be impossible to produce good refrigeration (food compartment temperatures less than 45°) in a standard 100 lb. box on a 90° day, unless the air circulation is improved.

But, for the sake of argument, assume that the refrigerating machine can be operated with a brine temperature of -9°. In order to refrigerate the box on a

90° day, a refrigerating effect equivalent to the melting of 2.12 lbs. of ice per hour would be required.

In order to make 12 ½ lbs. of ice, the following refrigerating effect would be required.

B.t.u.

To lower temperature of 12 ½ lbs. of
water from 80 to 32° ----- 600

To freeze 12 ½ lbs. of water ----- 1800

Total ----- 2400 B.t.u.

If this is done in eight hours, it is equivalent to a rate of 2.08 lbs. of ice per hour.

The food which is put in the refrigerator has to be cooled.

Suppose that after breakfast the following food is put in the refrigerator.

	<u>Approx. Wt.</u>	<u>Temp.</u>
2 Dozen eggs	2 lbs.	90°
Meat #	4 lbs.	60°
Butter #	2 lbs.	60°
Vegetables	2 lbs.	90°
2 Quarts of milk #	2 lbs.	60°
Dessert to be cooled	2 lbs.	90°
8 lbs. food cooled from 60° to 40°	- -	- 160 B.t.u.
6 lbs. food cooled from 90° to 40°	- -	- <u>300 B.t.u</u>

Total - - - 460 B.t.u.

Foot-note (#): It is assumed that these articles are delivered promptly from the store and have not warmed up to room temperature. Assume the specific heat of all of these to be unity.

If this is done in three hours, it is equivalent to a rate of 1.06 lbs. of ice per hour.

What is the effect of opening the door of the refrigerator? Suppose that each time the refrigerator is opened the whole food compartment fills with 90° air at 100 percent humidity. The food compartment has a capacity of 6.05 cu. Ft. This would represent .414 lbs. of air. In cooling this 90° air to 40°, about .011 lbs. of water will be condensed. The refrigerating effect required to cool the air and condense the water will be 16.8 B.t.u., which is equivalent to .1165 lbs. of ice. If the box is opened twelve times an hour, it is likely that 1.42 additional pounds of ice would be melted. The engineer of the Arlington Refrigerator Company, who was formerly with the Toledo Coldmaker Company, made some tests to determine the effect of opening the door of the re-refrigerator. He found that frequent opening and closing of the door increased the amount of ice meltage 27 percent. I have assumed that the refrigerator will be opened twelve times an hour in order to make an increase of 27 percent.

Adding all these together, the peak load on the refrigerating machine would be,

					Rate in lbs. of <u>Ice per hour</u>
To hold box at 40° with room at 90°	-	-	-	-	2.12
To freeze 12 ½ lbs. of ice in eight hours	-	-	-	-	2.08
To cool food in three hours	-	-	-	-	1.06
Opening the box twelve times-	-	-	-	-	<u>1.42</u>
Total	-	-	-	-	6.68

This is equivalent to a maximum rating of 160 lbs. of ice per twenty-four hours.

However, the average load would be much less than this.

	Lbs. of ice per <u>24 Hours</u>
To hold box at 40° with room at 70° -	- 30.8
To freeze 12 ½ lbs. ice once in 24 hours	- 15.7
To cool food once in twenty-four hours	- 2.35
Opening the box twenty-five times, each time filling with 70° air at 66% humidity - - -	- <u>.82</u>
Average daily consumption - - -	- 49.67

The new Fort Wayne type OC-2, form G machine would not be capable of holding the food compartment of this box at 40° on a 90 degree day, because the oil would freeze up if it was run with a brine temperature of -9°. Further, even if the oil did not freeze up, the capacity of the machine would only be about 80 lbs. of ice per twenty-four hours at this brine temperature, whereas, 160 lbs. of ice would be required.

On the other hand, a brine temperature of 20° would be correct for this box on an average 70 degree day. The Fort Wayne type OC-2, form G machine is capable of operation under this condition with approximately 45.5 watt-hours per pound of ice. It would, therefore, require 2.26 KW-hours per day.

Let us see what rating of machine would be required for use with a special 100 lb. box having an additional inch of cork insulation. (This would make a total insulation equivalent to 2 1/3 inches of Non-Pareil corkboard.)

In this case, on an average 70 degree day, the brine tank could be run at 32°, thereby obtaining a food compartment temperature of 40°, and the rate of ice meltage would only be .8 lbs. of ice per hour.

In order to maintain a 40° food compartment on a 90° day, it would be necessary to hold the brine tank at 18° and the rate of ice meltage would be 1.3 lbs. per hour.

	<u>Rate in lbs. of Ice per hour</u>
To hold the box at 40° with room at 90° - - - -	1.33
To freeze 12 ½ lbs. ice in eight hours - - - - -	2.08
To cool food in three hours - - - - -	1.06
Total - - - - -	4.47

This is equivalent to a maximum rating of about 108 lbs. of ice per twenty-four hours.

On the average 70 degree day, however,

	<u>Lbs. of ice per 24 hours</u>
To hold box at 40° with room at 70° - - - - -	19.2
To freeze 12 ½ lbs. ice once a day - - - - -	15.7
To cool food once a day - - - - -	2.35
Opening box twenty-five times - - - - -	<u>.82</u>
Total - - - - -	38.07

The brine temperature under this condition would be 32° instead of 21°, which would increase the efficiency of the machine about 20 percent. Therefore, about 36.4 watt-hours would be required per pound of ice and 1.4 KW-hours electrical energy would be consumed per day.

In comparing the standard box with the box having 1" additional cork insulation, it will be assumed that the 108 lb. capacity machine costs just as much as the 160 lb. machine. The difference in the power bills for six months' operation at five cents per KW-hour would be,

Standard box, 2.26 x 182 x .05	-	-	-	-	\$ 21.80
1" Additional cork, 1.4 x 182 x .05	-	-	-	-	<u>13.60</u>
Gross profit	-	-	-	-	\$ 8.20
Interest and depreciation on \$20.00 investment	-	-	-	-	<u>3.20</u>
Net profit	-	-	-	-	\$ 5.00

Assuming the machine is operated six months in the year, there is an annual net profit of \$5.00 on the investment in additional insulation. This is 25 percent of the \$20.00 investment.

These figures are very conservative because it is very likely that the machine would be operated more than six months during the year.

Of course, unless the refrigerator is located in a special room where the window is kept open, it may

possibly have to run with a 70° room temperature all the year. Mr. C. K. Nichols, sales manager of the New York Edison Company, is preparing figures for a report which will be read at the October meeting of the National Association of Edison Illuminating Companies. These figures have not been tabulated in scientific form as yet, but I had a chance to glance over them in Mr. Nichols' office, and my impression is that most of the machines carried about an average load all winter. For instance, one machine averaged 2 KW-hours per day for the year, but during the month of July the average was 2.3 KW-hours per day. Other machines averaged for the year 2.8 KW-hours, 2.7 KW-hours, 1.8 KW-hours, and 1.73 KW-hours.

If three extra inches of cork are added (making a total insulation equivalent to 4 1/3 inches of cork), the peak load of the machine would be reduced to a rating of 95 lbs. of ice per twenty-four hours. The average load would be 30.07 lbs. of ice per day, and the brine tank could be run at 37 1/2 degrees. The watt-hours per pound of ice would be 32.5.

The power bill for six months would compare as follows:

Standard box	-	-	-	-	\$ 21.80
Three extra inches of cork	-	-	-	-	<u>9.00</u>
Gross profit	-	-	-	-	\$ 12.80
Interest and depreciation on \$60.00 investment					<u>9.60</u>
Net profit	-	-	-	-	\$ 3.20

It will be noticed that the net profit is 5 1/3 percent of the \$60.00 investment.

THE FRIGIDAIRE HAS A 9 cu. ft. BOX WITH TWO INCHES OF CORK INSULATION, AND MAKES 9 lbs. OF ICE PER DAY.

The insulation consists of 2 inches of cork board, five ply laminated wood, and porcelain lining.

The outside area is 73 sq. ft

If the insulation is the equivalent of 2 1/3 inches of cork, the heat transfer on a 70 degree day through 73 sq. ft. to a 40 degree internal temperature would be about 1.37 lbs. of ice per hour.

Therefore, the average load would be,

	Lbs. ice per
	<u>24 hours</u>
To hold a temperature of 40° - - - - -	33 lbs.
To freeze 9 lbs. of ice - - - - -	11.3 lbs.
To cool food - - - - -	<u>2.35 lbs.</u>
Total - - - - -	46.65 lbs.

If the machine has the same efficiency as the Fort Wayne type OC-2 machine, this corresponds to about 2.14 KW-hours per day.

This checks very well with the actual performances. Mr. T. I. Jones' paper gave a figure of 1.8 KW-hours per day this machine. Mr. Grant told me the latest figure was 1 1/2 KW-hours, average for the year. Of course, during the winter months the temperature might be

less than 70 degrees, which would bring down the average.

It is interesting to calculate that the 12 ½ lbs. of ice for table use is made with an expenditure of only .71 KW-hours, or about 3 ½ cents, if the power costs five cents per KW-hour. This corresponds to 28 ½ cents per hundred-weight, whereas the purchase price of ice is about 60 cents to 80 cents per hundred-weight.

THE FORT WAYNE TYPE OC-2 MACHINE IS INSTALLED
IN A JEWETT REFRIGERATOR WHICH HAS,

- 1 – Interior space – 25.7 cu. ft.
- 2 – Food compartment – 19.5 cu. ft.
- 3 – Insulated area – 45" x 19" x 52" – 58 sq. ft.
- 4 – Insulation – 7/8" ash case,
2 courses waterproof paper,
2 courses 1 ½" corkboard,
½ " granulated – cork with binder.
White vitreous porcelain on
18 gauge steel.

I assume that this total insulation is equivalent to 3 ¾" of cork.

- 5 – The machine is arranged so that the temperature in the food compartment varies from 42° to 48°. The average is actually 46°
- 6 – The brine tank temperatures vary from 18° to 26° F.
- 7 – The area of the brine tank is 9.3 sq. ft.
- 8 – Mr. Crane estimates that the inside of the expansion coils will be 2° lower than the brine temperature.
- 9 – The area of the expansion coils is 7.7 sq. ft.

- 10 – The condenser consists of 294 sq. in. copper, plus 95 sq. in. of cast iron, which equals 389 total square inches.
- 11 – Mr. Crane estimates a difference in temperature between the inside of the condenser and the water of 6 or 9 degrees.
- 12 – The machine has two ice pans that will hold 4 lbs. each.
- 13 – Mr. Crane estimates about 8 lbs. of ice will be made each twenty- four hours.

If this machine has an equivalent insulation of 3 ¾ inches of cork, the B.t.u.'s per hour, per square foot, per degree, can be calculated from the table on page #5 of appendix #6 as .06. With 58 sq. ft. and a 24 degree temperature difference, this would correspond to 83.2 B.t.u. per hour or 14 lbs. of ice per day.

This box has two food compartments with a total of 19.5 cu. ft. If one of the doors is opened, approximately 9 cu. ft. of air at perhaps 70° and 66 percent humidity would enter the box. To cool this air to 46° would require a refrigerating effect of 6.42 B.t.u. If the door was opened twenty-five times a day, an additional refrigerating effect of 160 B.t.u. or 1.11 lbs. of ice would be required.

	<u>Lbs. of ice per 24 hours</u>
To hold box at 40° on 70° day -----	14
To freeze 8 lbs. of ice -----	10
To cool the food -----	2.35
Opening the box twenty-five times -----	<u>1.11</u>
Total -----	27.46

The old type OC-2, form E machine required 40.5 watt-hours per pound of ice. Therefore, the theoretical KW-hour consumption on an average 70 degree day would be 1.11.

The figures which Mr. Riffel took on Mr. Waters' machine show that the average of July, August, September, October and November, was 1.45 KW-hours per day. The variation was from 2.28 KW-hours in July down to .85 KW-hours in October.

It is also interesting to note that the water consumed by this machine during the same period averaged 4.72cu. ft. per day. # This varied from 7.85 cu. ft. in July down to 2.5 cu. ft. in November. At an average rate of 4.72 cu. ft. per day, in six months only 860 cu. ft. would be used. At \$1.00 per thousand cubic feet, this would correspond to a water bill of 86 cents. The amount of water taken by this machine is apparently very much less than that required by

Foot- note (#): There is some question as to the accuracy of the water meter at Mr. Waters' machine, but these readings check very well with the data obtained from tests at Fort Wayne. The machine running with an input of 340 watts, took eight gallons of water a day. If the power for the day is only 1.45 KW-hours, the machine only ran 18% of the time. It would therefore take $34 \frac{1}{2}$ gallons of 4.6 cu. ft. of water per day.

the Frigidaire. The Frigidaire, Model B-15, is advertised as taking from 20 to 30 cu. ft. per day average, which is from four to six times as much as this type OC-2 machine. This particular size of Frigidaire machine refrigerates 15.5 cu. ft., whereas the type OC-2 machine refrigerates 19.5 cu. ft.

APPENDIX 8
ANALYSIS OF TEST ON
TYPE OC-2 FORM "F" MACHINE

Mr. Hunting's report of January 31, 1922,
page 29, together with information contained in Mr. Crane's
letter of July 5, gives the following test figures:

Capacity	-	-	-	-	-	1210 B.t.u. per hour
Condensing water enters at	-	-	-	-	-	58 degrees
Condensing water leaves condenser at	-	-	-	-	-	77 degrees
Condensing water leaves water jacket at	-	-	-	-	-	88 degrees
Condensing water	-	-	-	-	-	8 gallons per hour raised 30° F.
Condenser pressure	-	-	-	-	-	48 lbs.
Brine temperature	-	-	-	-	-	23° Fahrenheit
Power input	-	-	-	-	-	.28 watt-hours per B.t.u.

In appendix #11, "Comparison of Various Refrigerants", it was shown that the theoretical coefficient of performance for sulphur dioxide between these temperatures is 7.11 for wet compression and 6.96 for dry compression.

If we assume wet compression, then
 $1210/7.11 = 170$ B.t.u. work will be required per hour to
 produce a refrigerating effect of 1210 B.t.u. If this work
 is done in one hours, the theoretical horsepower required
 will be .0666. Assume two degrees difference in temperature

between the brine and the inside of the expansion coils.

This makes an expansion coil temperature of 21°. Neglecting efficiency, this corresponds to 49 ½ watts.

But, the electrical input was 340 watts.

Therefore, the losses in the motor and compressor must have been 290.5 watts which, expressed in heat units, is equivalent to 995 B.t.u. per hour. On the temperature-entropy diagram H-99384, which shows the wet compression of one pound of sulphur dioxide, it will be noted that the condenser must absorb 162.5 B.t.u. for every pound of sulphur dioxide circulated. It will be necessary to circulate 8 ½ lbs. of sulphur dioxide per hour to obtain a rating of 1210 B.t.u. per hour. Therefore, the condenser must absorb 1380 B.t.u.

Heat given off in the condenser by the cooling

and liquefaction of the sulphur dioxide - - - - - 1380 B.t.u.

Heat equivalent of the losses - - - - - 995 ``

Total - - - - - 2375 B.t.u.

Heat taken up by eight gallons of cooling

water raised 30 degrees - - - - - 2010 ``

Difference - - - - - 365 B.t.u.

Therefore, 365 B.t.u. per hour must have been radiated and convected from the case of the OC-2 machine.

The volume of 8 ½ lbs. of sulphur dioxide vapor at 21° F. is 38 cu. ft. Therefore, 38 cu. ft. of gas

must have been pumped per hour. The compressor of this form F machine had a displacement of 70 cu. ft. per hour. Therefore, the volumetric efficiency is about 54 percent. If this low volumetric efficiency were due to a large clearance in the end of the cylinder, it would not necessarily represent a power loss, but the clearance in these machines is very small, being a fraction of a percent. Therefore, most of this loss must be slippage past the piston. This seems like a very excessive slippage loss, but it might possibly be due to the fact that there are no piston rings in this type of compressor.

If this 46 percent loss in volume is due to slippage, it means that the indicated horsepower of the compressor is approximately 46 percent larger than would otherwise be the case. The indicated horsepower is, therefore, $\frac{.0666}{54} = .1225$.

The motor efficiency is assumed to be 60 percent so that with an input of 340 watts the output would be .274 horsepower.

Therefore, the mechanical efficiency of the pump must be $.1225/274 = 45$ percent.

The overall efficiency of the machine from the electrical input to the motor to the theoretical horsepower required to compress the gas would be $.0666.456 = 14.6$ percent.

This is assumed to be distributed as follows:

Motor efficiency - - - - - 60%

Mechanical efficiency - - - - 45%

Volumetric efficiency
due to slippage - - - - 54%

The heat given to the cooling water can be determined as follows:

Water enters - - - - - 58°

1380 B.t.u. given to the condenser by

8 gallons of water causes a rise of - - 20 1/2 °

Water must leave the condenser at - - - - - 78 1/2 °

Since the water leaves the water jacket at 88 degrees, it could only have risen 9 1/2 °, which would correspond to 630 B.t.u.

Temperature of the sulphur dioxide at 48 lbs. - - - - 82 1/2 °

The average condenser temperature - - - - - 68 1/4 °

Difference in temperature between the water
and the sulphur dioxide - - - - - 14 1/4 °

These tests are on the old Fort Wayne type OC-2, form F machine, which had a slow compressor consisting of two double acting cylinders with cranks at right angles geared to the motor. Within the last six months, the type OC-2 machine has been redesigned, the newer model

being called form G. This new machine has two single acting cylinders, direct connected to the motor. Tests on this new machine show a power consumption of .315 watt-hours per B.t.u. which is 12 percent more than with the old form F machine. The Fort Wayne engineers suggest that this additional loss is due to the more rapid stirring of the oil. I think it is probably due to the lower volumetric efficiency of the high speed compressor for the following reasons:

The capacity of the machine with 21° brine is only 1025 B.t.u. Therefore, only 32 cu. ft. of vapor must be pumped.

The displacement of the machine is 71 cu. ft. This makes a volumetric efficiency of 45 percent as compared with the 54 percent volumetric efficiency of the old form F machine.

I believe this would easily account for the additional 12 percent power required.

Condenser

In the above calculations, it was assumed that the average drop between the gas in the condenser and the cooling water was 15 degrees. The area of the condenser is 389 sq. in. 294 sq. in. of this consists of the 9/16 inch inside diameter pipe carrying water at the rate of eight gallons per hour. This corresponds to 0.173 feet per second.

On page 187 of "Elements of Refrigeration", by A. M. Green, Jr., there is a formula credited to R. L. Shipman,

$$K = 130 \sqrt{W}$$

Where, $K = \text{B.t.u. per square foot, per hour, per degree.}$

$W = \text{Velocity of water in feet per second.}$

Substituting a velocity of water of .173 ft. per second, the value of "K" becomes 54.

Therefore, the B.t.u. transfer through the 294 square inches of pipe, with an average difference in temperature of 15 degrees, would be,

$$\text{B.t.u.} = 54 \times 294/144 \times 15 = 1650$$

The actual heat transfer was 1380 B.t.u.

I have not calculated the heat transfer in the cast iron portions because the velocity of flow would be very small, making a very small value of "K".

Expansion Coils

The assumption of 2 degrees drop between the brine and the expansion coils was apparently not so conservative because the value of "K" for brine coolers given on page 189 of Professor Greene's book is 50. The expansion coils have 7.7 square feet. The heat transfer was 1210.

This requires a 3.16 degree difference.

APPENDIX # 8-A.

ANALYSIS OF TESTS ON TYPE OC-2 FORM G
MACHINE NO. 100 37-G.

EDITOR's note: diagrams or pictures referenced are too faded to be included

SUMMARY

The Carnot cycle coefficient of performance is,

$$\frac{T^2}{T^1 - T^2}$$

Although the absolute values of the coefficient of performance of a sulphur dioxide cycle and a Carnot cycle are not the same, for different conditions, their variation is proportional within an error of about 2 ½ %.

The overall efficiency of the motor and compressor = thermodynamic work divided by electrical input expressed in B.t.u. = a constant = 15.4%.

Since the overall efficiency is a constant, the actual electrical power per B.t.u. refrigerating effect will vary as the coefficient of performance. Therefore, if you have a test in which the electrical input per B.t.u. is E when the absolute temperature of the expansion coils is T² and the absolute temperature of the condenser T¹, then the electrical input per B.t.u., E', for the same machine operating between an expansion coil temperature T^{2'} and a condenser temperature T^{1'} will be,

$$E' = E \times \left(\frac{T^{1'} - T^2}{T^{2'}} \right) \times \left(\frac{T^2}{T^1 - T^2} \right)$$

It will be quite interesting to see whether this formula will check tests which are made over a wider range of temperatures.

The volumetric efficiency corresponding to the tests varies from 56% down to 46.7%. This could be accounted for by a 38.9% leakage and the re-expansion of a 12 ½ % clearance volume. I am wondering whether there is a sufficiently large bubble of gas still under the snifter discharge valve at the end of the compression stroke which might be sucked back into the cylinder, re-expanding and thus giving the effect of 12 ½ % clearance.

I - INTRODUCTION

When I was in Fort Wayne a short time ago, Mr. Clark Orr called my attention to the following tests on machine #10037-G.

TABLE I

Brine Temperature	: Condenser Gauge Pressure	: Refrigerating Effect	: Electrical Input
		: BTU per hour :	Watts
20°	: 48 lbs.	: 980	: 265
20°	: 58 lbs.	: 850	: 266
20°	: 69 lbs.	: 785	: 275

These figures are plotted on H-108944. Mr. Orr felt that it was very peculiar that this curve was concave upward. The fact that the curve is concave upward looks very promising for an air cooled machine because it shows that as
(Editors note: 2 pages of diagrams faded beyond recognition)

the condenser pressure rises and the temperature rises, the capacity of the machine falls off less rapidly than might otherwise be expected.

II- TEMPERATURE ENTROPY DIAGRAM – H-108945

The calculations for this diagram are given in Section VI at the end of this appendix. The diagram is based on the circulation of one pound of sulphur dioxide. The horizontal distance across the bottom represents the refrigeration which can be obtained by circulating one pound of sulphur dioxide. It will be noticed that due to the evaporation going through the expansion valve and due to the required moisture in order to maintain wet compression in the compressor, the possible refrigeration is considerably less than the latent heat of evaporation of one pound.

The following calculations are for three different conditions, all with a brine temperature of 20° Fahrenheit. I have chosen even temperatures of 80°, 90°, and 100°, because it avoids interpolations in the tables.

(Editors note: 2 pages of diagrams faded beyond recognition)

TABLE II

1	2	3	4	5	6	7	8	9	10
Calculation	CONDENSER Temp.	Guage	Refr. Effect per lb.	Work per lb.	Quality of mix- ture Entering comp	Volume of 1# of mix- ture to comp	Refr. Effect per cu. Ft.	Coeffi- cient of Perfor- mance	Ratio Coeffici- ent of Perfor- mance
			BTU	BTU		cu. ft.			
I	80°	45.2	143.4	19.6	93.5%	4.413	32.5	7.32	1.0
II	90°	56.87	137.	22.4	92.5%	4.364	31.5	6.12	.835
III	100°	70.2	133.	25.	92.2%	4.349	30.6	5.32	.726

Column 4 is the refrigerating effect per pound, taken from the temperature-entropy diagram.

Column 5 is the thermodynamic work theoretically required to compress a pound of sulphur dioxide from the expansion coil pressure to the condenser pressure.

Column 8 is the refrigerating effect per cubic feet actually pumped. It is the quotient of Column 4 divided by the thermodynamic work in Column 5.

Column 10 is the ratio of the coefficient of performance in calculation II and III to the coefficient of performance in calculation I.

In order to show that the variation in the coefficient of performance is dependent on the expansion and condenser temperatures, Table III has been prepared.

TABLE III

Calculation :	Temperature :	T^1 :	T^2 :	$T^1 - T^2$:	Carnot cycle Coefficient of Performance :	Ratio of Coefficients of Performance :
I	80	540	480	60	8.0	1.0
II	90	550	480	70	6.85	.86
III	100	560	480	80	6.0	.75

Column 3 is the absolute condenser temperatures. It is the temperature in Column 2 plus 460.

Column 4 is the absolute temperature of the expansion coils: it is 20° plus 460.

Column 5 is the difference between Column 3 and 4.

Column 6 gives the Carnot cycle coefficient of performance; it is, $T^2 / T^1 - T^2$, or Column 4 divided by Column 5.

Column 7 is the ratio of the coefficients of performance in calculation II and III to the coefficient of performance of calculation I.

It is interesting to notice that the last column of Table II is within $2 \frac{1}{2} \%$ of the last column of Table III.

III- COMPARISON OF THEORETICAL REFRIGERATING EFFECT PER CUBIC FOOT WITH THE ACTUAL REFRIGERATING EFFECT PER CUBIC FOOT DISPLACEMENT AS DETERMINED FROM TESTS.

For comparison with the theoretical analysis, I have rearranged the experimental data of Table I to show the refrigeration per cubic foot of displacement. I have also reduced the electrical watts input per B.t.u. refrigerating effect to its energy equivalent in B.t.u. It is my understanding that the form G machine has a displacement of 54.8 cu. ft. per hour.

TABLE IV

Gauge Pressure	:Refrigerating Effect : :per cubic Foot Dis- : : placement :	Electrical Input per B.t.u. Refrigerating Effect
48	: 18 B.t.u. :	.925 B.t.u.
58	: 15.6 :	1.078
69	: 14.3 :	1.2

Curve I on H-105447 is the refrigerating effect per cubic foot displacement from tests given in Table IV.

Curve II on the same H-105447 is the theoretical refrigerating effect per cubic foot from Column 8 of Table II.

Curve III on the same H-105447 is the ratio of Curve I divided by Curve II. It is the volumetric efficiency. Because if the compressor had pumped a volume equal to its displacement, the refrigerating effects from test on Curve I would have coincided with the theoretical refrigerating effect per cubic foot given in Curve II.

IV- COMPARISON OF THE THEORETICAL THERMODYNAMIC WORK WITH THE ACTUAL ELECTRICAL ENERGY INPUT TO THE MOTOR AS GIVEN BY TEST.

The theoretical thermodynamic work per B.t.u. is the reciprocal of the coefficient of performance, or it could have been determined directly by dividing Column 5 by Column 4 of Table II.

TABLE V

:Calculation	:	Thermodynamic work:	:
:	:	per B.t.u.	:
: I	:	.136	:
: II	:	.162	:
: III	:	.188	:

Curve I on H-105448 shows the theoretical thermodynamic work per B.t.u.

Curve II on H-105448 shows the electrical input per B.t.u.

Curve III shows the ratio of Curve I divided by Curve II. It is the overall efficiency of the motor and the compressor. It will be noted that the overall efficiency is a constant, 15.4%, throughout the range of the experiment. One reason for calculating the efficiency in this way is so that it will come out as a constant. It is then possible, if we have an experiment giving the electrical input per B.t.u. refrigerating effect with a certain expansion coil temperature and condenser temperature, to calculate the electrical input per B.t.u. for any other expansion coil temperature and condenser temperature by merely taking the ratio of the Carnot cycle coefficient of performance for each case.

V. It is interesting to note that the overall efficiency was a constant whereas the volumetric efficiency varied considerably. If the losses which cause volumetric efficiency were all due to leakage, we would expect the overall efficiency to vary with the volumetric efficiency. But, suppose the volumetric efficiency is due to a constant loss plus another loss of the nature of re-expansion in clearance spaces, any volumetric loss which is due to re-expansion in clearance does not mean loss in power.

These compressors are supposed to have a very small clearance. On the other hand, it occurs to me that there is a chance that at the end of the compression stroke there may be a good sized bubble of gas under the snifter valve, which would be sucked back into the cylinder at the

beginning of the suction stroke and then re-expand in the cylinder, giving the effect of clearance. In order to show this possibility, I have prepared Table VI.

Table VI indicates, therefore, that the assumption that the volumetric efficiency is due to 38.9% leakage and a re-expansion of a $12 \frac{1}{2}$ % clearance volume gives the same overall volumetric efficiency in Column 7 as the test volumetric efficiency in Column 4. This assumption would also be consistent with the experimental fact that the overall efficiency of the motor and compressor is a constant.

TABLE VI

Test	Gauge Pressure	Absolute Pressure	Compression Ratio	Volumetric Efficiency from test	Volumetric Efficiency due to leaks	Volumetric Efficiency from Ingersoll Rand curves corresponding to 12 ½% clearance	Product of Columns 5 & 6
I	48 lbs.	62.7	3.06	56. %	71.1 %	78.7 %	56.
II	58 lbs.	72.7	4.25	49.7 %	71.1 %	70.1 %	49.7
III	69 lbs.	83.7	4.89	46.7 %	71.1 %	65.7 %	46.7

VI – DETAILED CALCULATIONS FOR TEMPERATURE-ENTROPY DIAGRAM

Calculation #1

WET COMPRESSION CYCLE BETWEEN 20° and 80° F.

After compression at 80° Fah.

Gauge pressure = 45.2 lbs. per sq. in.

Total heat = H = 182 B.t.u.

Entropy = S = .3393

If the compression is adiabatic, the entropy must have been the same before compression as afterward.

Therefore, before compression at 20° Fah.

$$S = .3393$$

This requires that the quality be,

$$X = .935$$

Total heat = H = 162.4

Volume = 4.72 × quality = 4.4132

After condensation at 80°

Total heat = H = 19

Entropy = S = .0372

After expanding through nozzle with constant heat content, the temperature drops to 20°

Total heat = H = 19

This requires that the quality should be .1341.

The refrigerating effect is equal to the difference of the total heat before compression and after expansion, or

$$162.4 - 19 = 143.4$$

$$\text{Refrigerating effect per cu. ft.} = 143.4 / 4.4132 = 32.5$$

-12-

The work is equivalent to the difference in total heat before and after expansion, or

$$182 - 162.4 = 19.6$$

$$\text{Work per cu. ft.} = 19.6 / 4.4132 = 4.44$$

Calculation #2

WET COMPRESSION CYCLE BETWEEN 20° and 90° F.

After compression at 90° Fah. and gauge pressure of 56.87 lbs.

$$H = 180^\circ$$

$$S = .3356$$

Before compression at 20° Fah.

$$S = .3356$$

This requires that the quality should be

$$X = .9253$$

$$H = 160.6$$

$$\text{Volume} = 4.364$$

After condensation at 90°

$$H = 23$$

$$S = .0445$$

After going through nozzle, the temperature drops to 20°

$$H = 23$$

$$X = .1564$$

$$\text{Refrigerating effect} = 160.6 - 23 = 137.6$$

$$\text{Refrigerating effect per cu. ft.} = 31.5$$

$$\text{Work} = 183 - 160.6 = 22.4$$

$$\text{Work per cu. ft.} = 5.11$$

Calculation #3

WET COMPRESSION CYCLE BETWEEN 20 degrees and 100 degrees F.

After compression at 100 degrees F., the gauge pressure is 70.2 lbs.

$$H = 185$$

$$S = .3342$$

Before compression at 20 degrees F.

$$S = .3342$$

This requires that the quality should be.

$$X = .9215$$

$$H = 160$$

$$\text{Volume} = 4.349$$

After condensation at 100 degrees

$$H = 27$$

$$S = .0518$$

After going through nozzle

$$H = 27$$

$$\text{Quality, } X = .1787$$

$$\text{Refrigeration} = 160 - 27 = 133$$

$$\text{Work} = 185 - 160 = 25$$

$$\text{Work per cu. ft.} = 5.75$$

January 16, 1924

APPENDIX # 8-B

AN EFFORT TO EXPLAIN THE LOW VOLUMETRIC AND
MECHANICAL EFFICIENCY OF THE OC-2 FORM H MACHINE

EDITOR's note: diagrams or drawings referenced are too faded to be included

Tests made on the $\frac{3}{4}$ " stroke by 1-1/8" diameter machine. If there are 1-1/2 thousandths clearance in the end of the cylinder, the total clearance volume, neglecting suction and discharge ports, would be 2.26%. However, the clearance between the piston and the end of the cylinder is likely to be more than 1-1/2 thousandths, and we have, therefore, assumed a total clearance volume of 4%.

With a 26° brine temperature, the absorption from the brine tank was 795 B.t.u. The probable leakage up the expansion and suction tubes may have been 14 B.t.u., making a total refrigerating effect of 809 B.t.u.

In the Evaporator-

$$P^1 = 16.9 \text{ lbs. absolute}$$

$$T^1 = 19.36^\circ \text{ Fahrenheit}$$

$$H^1 = 184.66 \text{ B.t.u. per lb.}$$

$$S^1 = .398$$

$$V^1 = 4.6 \text{ cu. Ft. per lb.}$$

Inside the Cylinder-

The walls of the cylinders are probably around 150°F. (This will be checked by future tests.) The vapor pressure of the oil at 150° F. is approximately 4.28 ice. Since the total suction pressure is 16.9 lbs., the partial

-2-

pressure of the refrigerant would be 12.62 lbs. At the end of the suction stroke, the cylinder is therefore filled with vapor under the following conditions.

$$P_2 = 12.62 \text{ lbs.}$$

$$T_2 = 150^\circ \text{ F.}$$

$$H_2 = 208 \text{ B.t.u.}$$

$$S_2 = .445$$

$$V_2 = 7.4 \text{ cu. Ft. per lb.}$$

At the End of Compression-

The condenser pressure is 106.7 lbs. absolute, and there is a probable drop in the discharge valves of 13.3 lbs. Therefore, at the end of compression the vapor in the cylinder is under the following conditions.

$$P_3 = 120 \text{ lbs.}$$

$$T_3 = 355^\circ \text{ F.}$$

$$H_3 = 250 \text{ B.t.u.}$$

$$S_3 = .445$$

$$V_3 = 1.2 \text{ cu. Ft. per lb.}$$

Re-expansion in Clearance-

Four percent of this re-expands, and after re-expansion the conditions are:

$$P_4 = 12.62 \text{ lbs.}$$

$$T_4 = 150^\circ \text{ F.}$$

$$H_4 = 208 \text{ B.t.u.}$$

$$S_4 = .445$$

$$V_4 = 7.4 \text{ cu. ft. per lb.}$$

It will be noted that this 4% expands from a volume of 1.2 cu. ft. per lb. to a volume of 7.4 cu. ft. per lb. Therefore, the volume has increased from 4% to 24.7%. This is equivalent to a volumetric efficiency of 75.3% due to re-expansion. There was another volumetric efficiency due to the fact that the volume in the expansion coils was 4.6, whereas the rise in temperature and reduction in pressure when entering the cylinder increased on volume per lb. to 7.4. This represented a volumetric efficiency of 62.3%. The overall volumetric efficiency would be the product of these two, or 46.7%.

Refrigerating Capacity-

If the gas is condensed at 106.7 lbs. and 116° Fahrenheit, the total heat per pound of the liquid will be 51 B.t.u. This will not change going through the expansion valve. The refrigerating capacity is, therefore, equal to,

$$184.66 - 51 = 133.66 \text{ B.t.u. per lb.}$$

Since the machine did 809 B.t.u. per hour, it must circulate 6.05 lbs. per hour, with an apparent volume of 4.6 cu. ft. per lb. There must, therefore, be sucked out of the evaporator 27.7 cu. ft. per hour which, with a volumetric efficiency of 46.7% and total displacement of the compressor of 59.5 cu. ft. per hour, exactly corresponds to a two cylinder, single acting compressor, 3/4" stroke by 1-1/8" diameter, running at 1150 r.p.u.

Work per Pound-

The work per pound is the difference between

-4-

H3 and H2, is we neglect the work of re-expansion: this gives 42 B.t.u. The coefficient of performance is the refrigerating effect divided by work, or

$$\frac{133.66}{42} = 3.18$$

$$\text{Work required per B.t.u.} = \frac{1}{3.18 \text{ B.t.u.}}$$

$$\text{Energy is watt-hours per B.t.u.} = \frac{1}{3.18 \times 3.414} = .09 \text{ watts per}$$

The motor takes .406 watts per B.t.u. The motor efficiency is 46.7%. Therefore, the motor output is .190 watts. The compressor mechanical efficiency must be,

$$.09 / .406 = 47.4\%$$

The overall electrical and mechanical efficiency is,

$$.09 / .406 = 22.2\%$$

While at Fort Wayne, I calculated the clearance volumes of the standard 1" diameter by 3/4" stroke oscillating cylinder compressor.

Drawing H-105455 shows the suction part of the machine. The dotted line is the outline of the hole at the inside of the cylinder wall, whereas the heavy line is the outline of the hole at the valve seat. The area at the valve seat is about .04496 sq. in. and at the inner wall is .0611 sq. in. The average area is, therefore, .05303. The depth through the cylinder is .187". The volume of the suction part is therefore .00994 cu. in.

Drawing H-105456 shows the outline of the discharge valve at the inside of the cylinder wall. It had an area of .0653 sq. in. The discharge valve at the outside is 1/8" diameter and has an area of .049 sq. in. This makes an average area of .05715 sq. in. The depth is .206"; the volume of the discharge port is, therefore, .0118 cu. in.

There is a groove in the cylinder head, the volume of which may be approximated by that of a triangular pyramid, 1/32" altitude of base by .1375 width of base by .625 height = 6.7×10^{-4} cu. in. A more accurate calculation by another method shown 6.1×10^{-4} cu. in.

SUMMARY OF CLEARANCE VOLUME

Volume of suction valve	.00994 cu. in.
Volume of discharge valve	.01180 " "
Volume of groove in cylinder head	.00061 " "
Volume of clearance between piston and end of cylinder = $\pi/4 \times (1)^2 \times .0015$	<u>.00118 " "</u>
Total clearance volume	.02353 cu. in.

/ The clearance between the piston and the end of the cylinder is probably, in a great many cases, considerably more than 1 1/2 thousandths, as assumed.

$$\text{Total volume} = \pi/4 \times .75 = .59 \text{ cu. in.}$$

$$\text{Percent clearance volume} = .02353 / .59 \times 100 = 4\%$$

The 3/4" stroke by 1 1/8" diameter cylinder is the same as the 1" diameter cylinder, except bored at 1/8" bigger diameter. The ports are, therefore, 1/16" shallower. The volume can therefore, be found by proportion from the foregoing.

Volume of suction valve	.00661 cu. in.
Volume of discharge port	.00824 " "
Volume of groove (same as before)	.00061 " "
Volume in end of cylinder = $\pi / 4 \times (1-1/8)^2$ × .0015/	<u>.0015 " "</u>
Total clearance volume	.01696 cu. in.
Total volume = .75 cu. in.	

$$\text{Percent clearance volume} = 2.26\%$$

DROP THROUGH SUCTION VALVE

Drawing H-105457 shows the area of the suction valve with the cylinder at various angular positions.

Curve H-105458 was prepared by counting the squares on drawing H-105457.

Drawing H-105459 shows the calculated distance of the piston from the head and, plotted against the crank angle. The solid line shows calculated values and the dotted line show Mr. Orr's measurements.

The full line on drawing H-105460 shows the theoretical valve opening in inches. The circles show Mr. Orr's measurements.

/ The clearance between the piston and the end of the cylinder is probably, in a great many cases, considerably more than 1 ½ thousandths, as assumed.

The values between 67 and 180 degrees on curve I of drawing H-105461 were prepared by the use of curves H-105458 and H-105460. The values from zero to 67 degrees on the same curve were prepared by the use of curves H-105459 and drawing H-105455. This curve shows how the piston restricts the valve opening near the head end of the stroke. This is not a disadvantage in the suction stroke because, due to re-expansion in the clearance volume, the piston would probably not try to suck air during the part of the stroke when the suction part is partly covered by the piston.

Curve II on drawing H-105461 was prepared from a combination of curve H-105459 and drawing H-105456. It shows the way the discharge valve is restricted when the piston is near the head end. The maximum area of the discharge valve is further restricted by the fact that it tapers to a 1/4" diameter hole at the outside.

The velocity of the piston at any instant is,

$$Rw \sin G$$

Where: $w = 120$

$$R = .375''$$

$$? = Rw = 45$$

The area of the piston is, $A = \pi/4 \times (1)^2$.

The drop through the suction valve can be calculated as follows.

G	sinG	Cu. in. per sec	Area of Valve Suction	Velocity thru valve Suction in/sec	Velocity Suction ft/sec	K.N.	Pressure Drop
0	0	0	0	0	0		
15	.258	9.14	.001275	7160	597	5540	8.35
30	.517	17.75	.0073	2435	202		
45	.707	25.1	.0175	1432	119		
60	.866	30.7	.0324	948	79		
75	.965	34.2	.0410	834	69.4		
90	1. 35.45		.0410	864	72		
105	.965	34.2	.0381	897	74.8		
120	.866	30.7	.033	930	77.5		
135	.707	25.1	.026	966	80.4		
150	.5	17.75	.0175	1015	84.6		
165	.258	9.14	.0084	1085	90.5		
180	0	0	0	0	0		

It will be seen that the drop through the suction valve would only be excessive during the first part of the stroke where, as already noted, the re-expansion of the clearance would prevent the piston's sucking air.

DISCHARGE VALVE

G	Cu. In. Per sec	Area of Discharge Valve	Velocity Discharge Valve in/sec	Velocity Discharge valve ft/sec	K.H. per Lb.	Pressure Drop
0	0	0	0			
2	1.238	.0000644	19250	1600	39750	276
4	2.476	.000257	9650	805	10050	70
6	3.705	.00058	6380	534	4420	30.8
8	4.95	.001025	4830	404	2530	17.6
10	6.16	.0016	3860	322	1610	11.2
15	9.14	.00280	3260	271	1140	7.92
30	17.75	.01351	1315	109.5	186.2	1.29
45	25.1	.02963	848	70.5	77.4	.536

It will be noticed that there is a tendency for the drop through the discharge valve to become very great toward the end of the stroke because of the restriction of the port.

The values of pressure drop shown are imaginary because before the pressure rose to these high values the air would compress in the clearance volume.

DISCHARGE VALVE SPRING

It took $\frac{1}{4}$ lb. spring balance to raise the discharge valve spring. The discharge valve is a $\frac{1}{4}$ " diameter hole, having an area of .0491 sq. in. Therefore, a pressure of at least 5.08 lbs. per sq. in. would be required to raise the valve.

The spring of the discharge valve is tuned three and one-half tones below Middle C. Middle C has 258.5 beats per second. A note three and one-half tones below Middle C would have 211 beats per second. It would take half a beat for the valve to rise and fall; therefore, it seems likely that when the pressure risen sufficiently to open the valve, it will open, the pressure will equalize, and the valve will tend to fall again, receding in perhaps $\frac{1}{422}$ seconds.

The main crank moves about eight degrees in this time. It seems likely that the discharge valve will probably oscillate two or three times at each opening, until the pressure drop due to the restriction will hold it open at the end of the stroke.

Curve H-105463 shows the cylinder volume, including the clearance volume, for different crank angles measured from the head end position.

Curve H-105462 shows the approximate pressure corresponding to various specific volumes.

TESTS ON THE OC-2 FORM "H" MACHINE #10053.
WITH 1 1/8" DIAMETER BY 3/4" STROKE OSCIL-
LATING CYLINDERS.

Schenectady, Feb. 2, 1924.

Mr. Robert Steck,
Farm Power & Lighting Engr. Dept.,
Fort Wayne Works.

Dear Mr. Stock:

I have gone over Test #2 and Test #5 which were attached to your letter of January 26th.

I made curve H-105480 for my own use, giving the calibration of brine tank #46. I believe that it is quite important that this calibration be checked by maintaining various temperatures with an electric heater. By this time, you will have received a report from me, showing the calculations on the heat flow through the 4" of cork insulation in the Odin box under transient conditions. These calculations on the Odin show the type of error which we ran the chance of by our old-fashioned method of testing.

I wish you would send me a complete specification of our brine tank, giving the dimensions and the materials. It may be possible to set up a set of equations from which the true amount of refrigeration can be calculated from these transient runs.

On the other hand, to use theoretical equations at all, it is necessary to know the exact temperature conditions in the cork before starting a run. It is my understanding that at present Mr. Orr heats up the inside of the brine tank rapidly with an electric heater after each refrigeration test. The result is that perhaps in the middle of the wall, the work is still at a low temperature, whereas the outside is at room temperature and the inside has also been heated up to room temperature. A run started with this distribution of temperature would probably give entirely different results from a run started with everything equalized.

I notice in going over the tests on the refrigerating machine, that you have started the runs at 32°. We are all agreed that the end points of these runs are very inaccurate

and it is, therefore, impossible to form an accurate estimate from these tests of the refrigeration capacity at 32°. We should either make tests by means of a balanced electric heater at 32°, or else start our runs at about 40°.

The following table gives my calculations based on Test #2:

Time	Brine Temp	ΔF	BTU per Hour	Diff. Bet. Room and Brine	Avg. Diff.	BTU From Curve	Total	Watts	Watts
2:05	32			43.5				322	
		3.1	1025		45.3	88	1113		318 ½
2:20	28.9			47.1				315	
		2.1	695		47.6	92	787		313
2:35	26.8			48.2				311	
		2.3	760		49.6	96	856		313 ½
2:50	24.5			51.1				316	
		2.0	660		52.	100	760		315 ½
3:05	22.5			53				315	
		1.7	562		53.5	103	665		311 ½
3:20	20.8			54				308	
		1.0	330		55.	106	436		305 ½
3:35	19.8			56				303	
		2.7	895		56.8	109	904		301 ½
3:50	17.1			57.7				298	
		1.6	530		59.	114	644		296 ½
4:05	15.5			60.3				295	
		1.5	496		60.4	116	612		292 ½
4:20	14			60.5				290	

Curve H-105481 shows this data plotted. The circles with creases in them indicate the calculations based on Test #5, which are as follows.

During a 2 ¾ hour run, the average watts to the heating unit were 216 watts or ----- 740 B.t.u. The average temperature differences between the room and the brine was 53.9°. The radiation from curve H-105480 -- 104 " "

Total refrigeration effect ----- 844 B.t.u.

The average watts input to the motor during this time was 308. The wathours per B.t.u. = 308/844 = .365.

Very truly yours,

ARStevenson, Jr-DW

APPENDIX #9

DISCUSSION OF THE POSSIBLE REDESIGN OF THE
FORT WAYNE TYPE OC-2 MACHINE FOR AIR COOLING

1. The condenser at present consists of a copper tube carrying water through the gas chamber. This tube is 12 ft. 3 in. long, and it had an outside diameter of 5/8".

Let us assume that this same pipe is placed out in the air and the gas piped through it.

The total heat transfer required is about 2000 B.t.u. per hour, or 585 watts.

This is very conservative because, as was shown in appendix # , "Analysis of Tests on the Type OC-2 Machine", although 2000 B.t.u. per hour was absorbed by the cooling water, only 1380 B.t.u. of this was absorbed in the condenser and the rest was either given off in the water jacket or dissipated directly from the case.

Mr. Chester Rice has given me a formula for the convection of heat from cylinders.

$$W_c = .0067 D^{3/4} L P^{1/2} \frac{T_{avg} .754}{T_{amb} .877 \Delta t}$$

Let, $D = 5/8" = 1.58 \text{ cm.}$

$L = 12' 3" = 357 \text{ cm.}$

$P = 1$

-2-

$$T_{amb} = (460 + 70) \div 1.8 = 530/1.8 = 295^\circ \text{ K.}$$

Assume $\Delta t = 10$ degrees

$$T_{avg} = 300^\circ \text{ K.}$$

Substituting in the formula,

$$W_c = 17.85 \text{ watts.}$$

The formula for radiation of heat is as follows:

$$W_r = 5.7 \times A \times e [(T_1/1000)^4 - (T_2/1000)^4]$$

$$A = 1870 \text{ sq. cm.}$$

$$c = 1 \quad (\text{I assume the pipe can have a black furnace.})$$

$$T_2 = 295$$

$$T_1 = 305$$

$$W_r = 5.7 \times 1.87 \times 10^3 \times 1.08 \times 10^{-3} = 11.5 \text{ watts}$$

With a 10° Centigrade rise (18° Fahrenheit rise), we have calculated that a length of pipe 12 ft. 3 in. long will dissipate 17.85 watts through convection and 11.5 watts through radiation, making a total of 29.35 watts.

In order to dissipate 2000 B.t.u. per hour (585 watts), a Length of pipe twenty times as long would be required, or 245 feet.#

I notice that the present condenser coil, 12 ft. 3 in. long, has a material charge of 89 cents and a labor charge of 20 cents. Assuming that both the material and the labor together are in direct proportion to the length, a coil 245 ft. long would have a,

Material charge -----	\$ 17.80
Labor -----	4.00
140% Labor overhead -----	<u>5.60</u>
Additional factory cost -----	\$ 27.40

From this could be subtracted about \$7.40, covering the various parts which are now included for the automatic control of water. Therefore, the condenser could be changed for air cooling at an additional factory cost of about \$20.00.

I assume that the motor housing could be cast with fins for about the same price that the present water jacket is included.

Foot-note (#) : These calculations are made on the basis of still air, and it is possible that if this pipe is coiled in the form of a chimney, less would be required.

The Kelvinator has 20 turns of pipe and I imagine the rectangles are about 35" x 20". This corresponds to about 185 ft. of pipe.

The Kelvinator probably does not rise more than 18°F., due to the chimney action and the windage from the motor, etc.

ECONOMY OF AIR COOLED OPERATION.

Having built the condenser for an 18 degree rise, on a 70 degree day this machine would run with a condenser temperature of 38°F.

In the appendix on the type OC-2 water cooled machine, it was calculated from the pressure that the condenser temperature was 82 ½ degrees.

From a theoretical Carnot cycle standpoint, a machine operating between 88° and 21° would require 9 per cent more power than a machine operating between 82 ½° and 21°. This is also consistent with the tests shown on H-99373.

In the appendix on the factors determining the proper rating for ice machines, it was pointed out that Mr. Waters' type OC-2 water cooled machine required on the average 1.45 KW-hours per day. But, this was with the older slow speed compressor. The new high speed compressor requires .315 watt-hours per B.t.u., which is

$$.315/.28 = 112\%$$

twelve percent more than the old machine under the same conditions. It would, therefore, have taken about 1.62 KW-hours per day. At five cents per KW-hour, the power bill would have

been about \$14.50 for six months. At \$1.00 per thousand cubic feet, the water would have cost 86 cents for the same period.

Nine percent of \$14.50 is \$1.30. Therefore, The power bill for the air cooled machine would probably be \$1.30 more in six months. Of course, the 86 cents water bill would be saved.

I would point out, however, that this comparison is not really fair to the air cooled machine because the water here in Schenectady is very cold, even in the hottest part of summer it never gets above 59°.

The actual hottest temperature of the water supply during the summer for twenty-one cities in New York, Georgia, and Texas, averages about 70°, and ranges anywhere from 50° to 90°.

For the extreme case, let us assume that the air temperature is 110° and the water temperature is 90°.

On a ninety degree day, about 50 percent more refrigeration would be required.

On June 15, 1923, Mr. Crane made a test on machine #10045, with the water leaving at 123 degrees. The condenser pressure was 90 lbs. This corresponds to about 102°. With the brine tank at 19.6 degrees, the power input was 332 watts and the machine was absorbing heat at the rate of 716.9 B.t.u. per hour. This is at the rate of 120 lbs.

of ice a day and 8 KW-hours per day. The energy input is .465 watt-hours per B.t.u. This is about 47 percent greater than the other test under normal conditions.

Due to the 82 degree difference in temperature instead of a 61.5 degree difference, we would theoretically expect about 35 percent increase in power. The other 12 percent may be due to the fact that the volumetric efficiency might have been worse at these higher pressures.

The power bill for six months at 3.6 KW-hours a day with a five cent rate would be about \$33.00.

The amount of heat taken up by the cooling water and radiation must have been 716.9 B.t.u., plus 1100, or 1816.9 B.t.u.

About 850 of this B.t.u. must have been in the condenser. The drop would, therefore, be,

$$14 \frac{1}{4} \times 850/1380 = 8.8 \text{ degrees.}$$

The average temperature of the condensing water must have been about $102 - 8.8 = 93.2^{\circ}\text{F}$.

If four gallons of water per hour are used, the rise in the condenser would be 34.8 degrees; the water entering would be $93.2 - 17.4 = 75.8$, and leaving would be 110.6.

The heat taken from the water jacket would be about half of 967 or 482 B.t.u. The rise would be about

14.6 degrees. This would make the outgoing water 125.2° F. , which checks fairly well with the value of 123°F.

In order to maintain a condenser temperature of 102° F. with water entering at 90°, it would be necessary to use,

$$4 \times 17.4/3.2 = 22 \text{ gallons of water per hour.}$$

The machine would run 46 percent of the time so that the daily water consumption would be 245 gallons per day, or 32.5 cu. Ft. At \$1.00 per thousand cubic feet, the water bill in six months would be \$6.00.

The total cost of operation would be \$39.00 for the six months.

The above water bill is unreasonable.

Suppose that we assume the rise to be 30°. Then, the average temperature would be 105 degrees, and the condenser temperature would be 115 degrees.

It can be seen from curve H-99373 that the capacity of the machine would be 689 B.t.u. , with a corresponding input of 340 watts.

The 340 watts input represents 1160 B.t.u.

The total B.t.u. which must be taken care of by the cooling water is the sum of the equivalent of the watts input and the refrigerating effect, or ----- 1849 "

The B.t.u. given up in cooling and liquefying The sulphur dioxide is ----- 840 "

Difference ----- 1009 B.t.u.

It is likely that half this difference is radiated from the case and the other half taken up by the cooling water. The requirements for cooling water would be,

Condenser - - - - -	689 B.t.u.
Water jacket- - - - -	<u>504 "</u>
Total - - - - -	1193 B.t.u.

If the cooling water is allowed up to rise thirty degrees, 4 ³/₄ gallons per hour will be required,

The machine would have to run 46 percent of the time. Therefore, the daily consumption would be 3.76 KW-hours electrical energy and 48 gallons, or 6.4 ou. Ft. of water.

The six months power bill
would be - - - - - \$ 34.20

The six months water bill
would be - - - - - 1.16

Total for six months' bill - - \$ 35.36

The air cooled machine operating in a 110 degree room would have a condenser temperature of about 130 degrees.

A condenser temperature of 130 degrees would correspond to about 126 lbs. per square inch.

From H-99373 it can be seen that with 130 degrees condenser temperature, .6 watt-hours per B.t.u.

or about 4 ½ KW-hours per day would be required. # Therefore, the six months' power bill would be \$41.00 as against \$35.36. If these extreme conditions lasted for six months, the water cooled machine would show a saving of \$4.64.

These figures for the 90 degree day, of course, should not be applied to so long a period as six months because there is no place in the country where such temperatures would last for six months.

I would also point out that the amount of water used by the type OC-2 machine is very much less than the Frigidaire. The records at Mr. Waters' show a maximum of 7.85 cu. Ft. per day in July, whereas the corresponding size Frigidaire machine is advertised as taking 20 to 30

Foot-note (#): On May 23, 1923, Mr. Crane ran a test at 125 lbs. condenser pressure which showed that 471 watt-hours were required to produce 480 B.t.u. This is at the rate of .98 watt-hours per B.t.u. This is 58 percent more power than we figured from the other tests. It would seem to indicate that at these high temperatures and pressures the oil seals on the compressor pistons and valves ceased to function properly. However, I do not feel that this test is reliable because it was run with very small quantities of cold water instead of a lot of warm water. In fact, the water was turned on and off continually in an attempt to adjust the temperature. If this test is correct, then if the room temperature was 110 degrees Fahrenheit for six months, the power bill for the air cooled machine would be 1.63 times the water cooled power bill.

It seems obvious from curve H-99373 that this test is wrong.

cu. Ft. per day. Of course, if the machine took 30 cu. ft. of water, this water charge would be \$1.87 multiplied by 30, divided by 7.85, which would be \$7.15, which would more than balance the power bill of the air cooled machine unless Mr. Crane's test at 126 lbs. is correct.

In redesigning this machine for air cooling it may be necessary to increase the cylinder sizes in order to maintain a capacity of approximately equivalent to the melting of 100 pounds of ice per days, which rating would be required by the Balsa box on a 90° day.

(Editors note: Curve H-99373 faded beyond recognition)

APPENDIX #10.
ABSORPTION MACHINES

The following theoretical example is worked out for comparison with the calculations made in appendices Nos. 11, for compression machines. The temperature of the expansion coils is assumed to be 21°F., and the temperature in the condenser and generator which can be obtained by means of cooling water is assumed to be 82 ½ °F. The machine will be assumed to operate with ammonia and water.

The system will be very simple, consisting only of a generator and condenser, an expansion valve, and expansion coils. The generator will also be used as the absorber.

The concentration in the absorber can be obtained from the formula,

$$T_{\text{sat}}/T_{\text{sol}} = .0047x + .655 \quad (1)$$

$$T_{\text{sat}} = 21 + 459.6 = 480.6$$

$$T_{\text{sol}} = 82 \frac{1}{2} + 459.6 = 542.1$$

$$? \quad x = 48.8\%$$

The condenser will also run at 82.5 degrees

The saturation pressure is 159.65 lbs/in²
absolute.

Assume that the generator pressure is
165 lbs.

Assume that the generator can be heated
to 300 degrees by means of an electric heater.

The saturation temperature corresponding
to 165 lbs. is 84.48.

The concentration of the solution remain-
ing in the generator would be 13.35 percent.

$$[(84.48 + 459.5)/(300 + 459.6) = .00471x + .655] \quad (1)$$

When the heat is turned on, the temperature is 82 ½ degrees.

For every pound of ammonia circulated in
this expansion coils, there must be in the generator-absorber
a certain quantity of liquor which can be calculated from
the concentration before and after absorption.

Let “y” be the number of pounds of weak
liquor of strength “X”, at 13.35% concentration, which must
be added to one pound of pure ammonia in order to obtain a
concentration X’. It can easily be shown that

$$y = (100 - X')/(X' - X) \quad (2)$$

$$X' = 48.8\%$$

$$X = 13.35\%$$

$$y = (100 - 48.8)/(48.8 - 13.35) = (51.2/35.54) = 1.444 \text{ lbs.}$$

Step #1 – Heating from 82 ½° to 165 lbs. pressure.

At the beginning of the heating period,
there is in the generator,

Liquor at (48.8% concentration) 2.444 lbs.

(t = 82 ½° F.)

(p = 49 ½ lbs.)

The specific gravity of this liquor at
60 degrees is given by the formula,

$$s_{60} = 1 - 4.3/1000 [x - x^2/100 + x^3/10,000] \quad (3)$$

$$x = 48.8\%$$

$$s_{60} = 1 - .157 = .843$$

The specific gravity at some other temper-
ature can be obtained,

$$s_{60} = s_t + .003(t - 60)(1 - s_t) \quad (4)$$

$$s_{82 \frac{1}{2}} = .831$$

The volume of this 2.444 lbs. is, therefore,
.047 cu. Ft., 81 cu. Inches.

It probably would not be practical to
attempt to make the generator just this volume.

Suppose the generator is 100 cubic inches.

This leave 19 cu. Inches = .011 cu. Ft. for vapor.

The vapor pressure of the steam would be,

$$\text{Vapor pressure } \times \text{psat } 1700 - 17 \text{ I}/1700 + x$$

At 82 ½ degrees,

$$\text{psat} = .5483$$

-4-

The ammonia vapor pressure would be,

$$49.5 - .5483 = 48.9517$$

Volume of 1 lb. of ammonia vapor, 48.9517 lbs.

and $82 \frac{1}{2}^{\circ} = 6.723$ cu. Ft.

Heat content per pound of ammonia = 576.26.

Volume 1 lb. of steam vapor, .5483 lbs. and

$82 \frac{1}{2}^{\circ} = 587.51$ cu. Ft.

Heat content per pound of steam – 1095 B.t.u.

Therefore in .011 cu. Ft., there would be

.00164 lbs. of ammonia vapor and .0000187 lbs. of steam.

We will neglect these.

Now, assume that the non-return valve from the expansion coils is closed and the heat turned on.

It will also be assumed that there is some liquid ammonia left in the condenser which will hold up the condenser pressure.

Therefore, the non-return valve to the condenser will not open until the pressure reaches 165 lbs.

The saturation temperature corresponding to 165 lbs. is 84.48° ?.; the temperature to which the 48.8 percent concentrated solution must be heated in order to get a pressure of 165 lbs. is given by the formula:

$$T_{\text{sat}}/T_{\text{sol}} = .00471X + .655$$

$$X = 48.8\%$$

$$T_{\text{sat}} = 84.48 + 459.6 = 544.08$$

$$T_{\text{sol}} = 544.08/.875 = 622 = 163.4 \text{ degrees}$$

Let us see whether the concentration of the solution could have changed during this heating.

The specific gravity of this liquor can be calculated by equations (3) and (4).

Then, $s_{162.4} = .722$

The liquor, therefore, expands in volume from .047 cu. Ft. to .054 cu. Ft. This only leaves .004 cu. Ft. for the vapors.

The vapor pressure of the steam can be calculated from equation (5).

$$P_{\text{steam at } 162.4^\circ \text{ F.}} = 5.017$$

$$X = 48.8\%$$

$$\text{Vapor pressure} = 5.017 - ((1700 - 17 \times 48.8)/(1700 + 48.8)) = 2.48 \text{ lbs.}$$

The ammonia pressure is,

$$165 - 2.48 = 162.52 \text{ lbs.}$$

The volume of one pound of ammonia vapor at 162.52 lbs. and 162.4° F. = 2.2466 cu. Ft.

The volume of one pound of steam at 2.48 lbs. and 162.4° F. = 149 cu. Ft.

Therefore, in .004 cu. Ft., there would be .0018 lbs. of ammonia vapor and .000027 lbs. of water vapor.

Therefore, .00016 lbs. of ammonia must have evaporated and .0000083 lbs. of water must have evaporated from the liquor during this heating. These quantities are so small that I believe then can be neglected.

The heat necessary to accomplish this preliminary heating can be estimated as follows.

At start:

.00164 lbs. of ammonia vapor at 576.26 B.t.u. per lb. = .945 B.t.u.

.0000187 lbs. of steam at 1095 B.t.u. per lb. = .0205 ``

Heat of liquid of 2.444 lbs. of liquor = 2.444
 $(82.5 - 32) = 123.0$ ``

Heat of partial absorption of liquor =

$-2.44 \quad 8.93 \times 48.8 - (1.42 \times (48.8)^2)/(51.2) = -905.0$ ``

Heat of absorbed vapor, $2.44 \times .488 \times 514.7 = \underline{611.0}$ ``

Total heat = -170.03 ``

At end of first step, when pressure reaches 165 lbs.:

.0018 lbs. of ammonia vapor at 607.1 B.t.u. per lb. = 1.09 B.t.u

.000027 lbs. of steam at 1130 B.t.u. per lb. = .0305 ``

Heat of liquid of 2.444 lbs. of liquor=
 $2.444 (162.4 - 32) = 319.0$ ``

Heat of partial absorption the same because
 the difference in concentration is neglected = -905.0 ``

Heat of absorbed vapor the same because the
 difference in neglected = + 611.0 ``

Total heat = + 26.12 B.t.u.

Therefore, 196.15 B.t.u. must have been

Supplied.

It would be necessary to add to this the heat necessary to change the temperature of the container and for radiation.

Step #2 – Heating from 162.4° to 230°.

The next step in the process is a boiling at a constant pressure of 165 lbs. , while the temperature rises and the concentration decreases.

In order to accomplish this step accurately, it would probably be necessary to split it up into five degree intervals in order to determine the exact amount of heat which leaves with the ammonia vapor.

In order to simplify this pressure, an intermediate point at 230° and a final point at 300° will be calculated and a curve drawn through the three points, including the first point at 162.4°.

At 230° and 165 lbs. pressure, the concentration can be determined by substitution in equation (1) as 28.6 percent.

The vapor pressure of the steam can be determined by substitution in equation (5). The saturation pressure at 230° F. is 20.78 lbs.

The vapor pressure is, therefore, equal to

$$20.78 \times ((1700 - 17 \times 28.6)/(1700 + 28.6)) = 14.6 \text{ lbs.}$$

The ammonia pressure is the difference between

$$165 \text{ lbs. and } 14.6 \text{ lbs., or} = 150.4 \text{ lbs.}$$

The specific volume of ammonia vapor at 150.4 lbs and 230° F.

$$= 2.766 \text{ cu. Ft.}$$

The heat content is approximately

$$648.1 \text{ B.t.u.}$$

The volume of one pound of steam at 14.6 lbs. and 230° is 27.84 cu. Ft. The heat content is approximately 1158 B.t.u.

Therefore, the number of pounds of steam per pound of ammonia is, $2.766/27.84 = .099$ lbs.

Before completing this step, it is necessary to draw several curves and for this purpose the characteristics at 300° are necessary.

At 300° and 165 lbs. pressure, the concentration has already been calculated as 13.35 percent.

The vapor pressure of the steam calculated from equation (5) is 57.6 lbs. The ammonia vapor pressure is, therefore, 107.4 lbs.

The specific volume of steam at 66.98 lbs. pressure and 300° F. is 6.46 cu. Ft. The heat content is approximately 1737 B.t.u.

Therefore, the weight of steam per pound of ammonia is $4.358-6.46 = .68$ lbs.

Curve H-99380 shows the ratio of pounds of steam to pounds of ammonia vapor for the three temperatures, 162.4° F., 230° F., and 300° F.

The curve has been sketched through those three points. It will be seen that between 162.4° F. and 230° F., the average ratio is approximately .05.

Starting with 2.444 lbs. of liquor at 48.8 percent concentration, how much liquor at 28.6 percent, concentration is left?

Let, y = Number of pounds of ammonia that
are boiled over.

Then, $.05 y$ = Number of pounds of water boiled over.

	Lbs. of Ammonia	Lbs. of Water
At Start	1.19	1.254
Loss	<u>y</u>	<u>.05 y</u>
At finish	$1.19 - y$	$1.254 - .05 y$
Concentration = .286 =	<u>$1.19 - y$</u>	
	$1.19 - y + 1.254 - .05 y$	

Solving this, $y = .7$ lbs. ammonia.

$.05 y = .035$ lbs. water.

This leaves 1.709 lbs. of liquor.

The specific gravity of the liquor at 28.6 percent concentration and 230° can be determined from equations (3) and (4) as .8. Therefore, the volume of 1.709 lbs. of liquor under these conditions is .0343 cu. Ft. since the tank contains .058 cu. Ft., this leaves .0237 cu. Ft. for vapor.

Since the specific volume of the ammonia vapor is 2.766, there would be room for .00855 lbs. Since the specific volume of the steam is 27.84 cu. Ft., there would be room for .00085 lbs. of steam.

WEIGHT BALANCE FOR GENERATOR WHITE HEATING FROM 162.4°F.
To 230°F.

At 162.4°

Lbs. of liquor at 48.8% concentration	2.444
Lbs. of ammonia vapor	.0018
Lbs. of steam	<u>.000027</u>
Total	2.445827

At 230°

Lbs. of liquor at 28.6 percent concentration	1.709
Lbs. of ammonia vapor	.00855
Lbs. of steam	<u>.000855</u>
Total	1.718405

The difference between these two totals must
have been driven off in the condenser = .727422

This difference is divided into water

vapor and ammonia vapor in the approximate ration of .05.

Therefore, Lbs. ammonia vapor	=	.692
Lbs. water vapor	=	.035422

HEAT BALANCE FOR GENERATOR

At 162.4°

Total heat already calculated + 26.12 B.t.u.

At 230°

To condenser	{.692 lbs. ammonia vapor at 622 B.t.u.}	
	{ per lb. = }	430 B.t.u.
	{.035422 lbs. steam at 1140 B.t.u. = }	40. ``

In clearance	{.00855 lbs. ammonia at 648 B.t.u. = }	5.5 ``
	{.000855 lbs. steam at 1158 B.t.u. = }	1.0 ``

Heat of liquid of 1.709 lbs. of liquor =
1.709 (230 – 32) = 330. ``

Heat of absorbed vapor (1.709 × .286 × 514.7) = 252. ``

Heat of partial absorption of liquor =
1.709 [8.93 × 28.6 – ((1.42 × (28.6)²)/71.4) = - 409. ``

Total heat at 230° = 649.5 B.t.u.

Total heat at 162.4° = 28.26 ``

Heat supplied to medium during second step = 623.24 ``

Additional heat would be required to heat the container from 162.4° to 230° and to supply the radiation loss.

Third step – “eating from 230° to 300° while the concentration changed from 28.6% to 13.35%.”

Starting with 1.709 lbs. of liquor at 28.6 percent concentration, how much liquor at 13.35 percent concentration will be left?

	Lbs. of Ammonia	Lbs. of Water
At start	.489	1.22
Loss	<u>y</u>	<u>.3 y</u>
At finish	.489 – y	1.22 - .3y
Concentration = .1335 =	<u>.489 – y</u>	
	.489 – y	+ 1.22 - .3 y

Solving this, Y= .317 lbs. ammonia

-3 y = .0951 lbs. water

This leaves 1.2969 lbs. of liquor.

The specific gravity of the liquor at 13.35 percent concentration at 300° can be determined from equations (3) and (4) as .82. Therefore, the volume of 1.2969 lbs. of liquor under these conditions is .0254 cu. Ft. This leaves .0326 cu. Ft. for vapor.

Since the specific volume of the ammonia vapor at 300° is 4.358 cu. Ft. there would be room for

.00148 lbs. Since the specific volume of the steam at 300° is 6.64 cu. Ft., there would be room for .00505 lbs.

WEIGHT BALANCE FOR GENERATOR WHILE HEATING FROM 230° to 300°.

At 300°

Lbs. of liquor at 13.35% concentration	1.2969
Lbs. ammonia vapor	.00748
Lbs. of steam	<u>.00505</u>
Total	1.30943

At 203°

Total	1.718405
-------	----------

Therefore, the difference must have been driven off into the condenser = .408975

This difference is divided into steam and ammonia in the approximate ratio of .3, which is the average of curve H-99380 between 230° and 300°.

Lbs. ammonia vapor	=	.314
Lbs. water vapor	=	.094975

HEAT BALANCE FOR GENERATOR

At 230°

Total heat of liquor and vapors remaining in generator = (649.5 – 470)
= 179.5

At 300°

To condenser	.324 lbs. ammonia at 662 B.t.u.	=	207.
	.094975 lbs. steam at 1360 B.t.u.	=	129.
In clearance	.00748 lbs. ammonia at 692.4	=	5.2
	.00505 lbs. steam at 1737 B.t.u	-	8.75

Heat of liquid of 1.2969 lbs. of liquor	=	
1.2969 (300 – 32)	=	348 B.t.u.
Heat absorbed vapor (1.2969 × .1335 × 514.7)	=	89.2
Heat of partial absorption of liquor =		
1.2969 [8.93 × 13.35 – (1.42 × (13.35) ²)/86.65]	=	<u>-150.5</u>
Total heat at 300°	=	636.65 B.t.u.
Total heat at 230°	=	<u>179.5</u> ``
Heat which must be supplied	=	457.15

Additional heat would be necessary to heat the container from 230° to 300° and to supply the radiation losses.

SUMMARY OF THE HEAT SUPPLIED TO THE GENERATOR.

First Step		
	B.t.u. consumed by medium	196.15
Second Step		
	B.t.u. consumed by medium	623.24
Third Step		
	B.t.u. consumed by medium	<u>457.15</u>
	Total =	1276.54 B.t.u.

Curve H-99381 has been drawn to show the process of heating from 162.4° to 300°. The curves are all drawn through three points, 162.4°, 230°, and 300°. The curve for B.t.u. required has been increased above that required to heat the medium by 45 B.t.u., to raise the tempe-

perature of the container. 19.12 B.t.u. for radiation during the first steps 38.3 to raise the temperature of the container and 62.32 for radiation during the second step: 39.5 to raise the temperature of this container and 35.71 for radiation during the third step.

It will be noted that the ratio, pounds of ammonia to B.t.u. required, comes to a maximum at approximately 230° and remains nearly constant, decreasing slightly up to 300°.

On the other hand, the pounds of water vapor per pound of ammonia increases quite rapidly after 230° is passed. As will be seen later, the amount of water vapor boiled over is a great disadvantage, and this could be largely overcome by not heating above 230°.

DETERMINATION OF AMOUNT OF COOLING WATER NECESSARY FOR CONDENSER

During the second step .692 lbs. of ammonia vapor were delivered to the condenser at an average temperature of about 190° F., having a heat content of approximately 622 B.t.u. per lb.	=	430 B.t.u
At the same time, .03542 lbs. of steam at approximately 1140 B.t.u. per pound were boiled over	=	40 B.t.u
During the third step .314 lbs. ammonia vapor at approximately 662 B.t.u. per pound	=	207 B.t.u
.094975 lbs. of steam at approximately 1360 B.t.u. per pound	=	<u>129 B.t.u.</u>
Total heat of vapors in condenser	=	806 B.t.u.

All of this must be cooled to 82 ½° and liquefied.

The possible concentration at 165 lbs. pressure and 82.5° F. can be determined from equation (1) as 77.3 percent.

After liquefying, there will be .130395 lbs. of water which can take up .444 lbs. of ammonia vapor, making .574395 lbs. of liquor at 77.3 percent concentration. This leaves .556 lbs. of liquid ammonia.

$$\text{Heat of liquid of .5744 lbs. of liquor} = \text{.5744 (82.5 - 32)} = 29$$

$$\text{Heat of absorbed vapor, (.5744} \times \text{.773} \times \text{514.7)} = 229$$

$$\text{Heat of partial absorption of liquor} = \text{.5744 [8.93} \times \text{77.3} - \text{((1.42} \times \text{(77.3)}^2\text{)/22.7)}] = -182$$

$$\text{Heat of .556 lbs. of liquid ammonia} = \underline{31.6}$$

$$\text{Total heat of liquor and ammonia leaving condenser} = 107.6 \text{ B.t.u.}$$

$$\text{Heat entering condenser} = \underline{806.}$$

Therefore, condenser must have removed – 698.0 B.t.u.

EXPANSION VALVE

In going through the expansion valve, the total heat must remain constant or 179.6 B.t.u.

The conditions in the expansion coils are 21° F. and 49.28 lbs. pressure. The concentration which is required under these conditions can be determined from equation (1) as 73 percent. Therefore, .22 lbs. of ammonia will be forced out of the solution. This leaves .3504 lbs.

of liquor at 73 percent concentration and .776 lbs. of ammonia.

$$\begin{aligned} \text{Heat of liquor of .3504 lbs. of liquor} &= \\ .3504 (21 - 32) &= -2.86 \end{aligned}$$

$$\text{Heat of absorbed vapor, } (.3504 \times .773 \times 514.7) - = 140.$$

$$\begin{aligned} \text{Heat of partial absorption} &= \\ .3504 [(8.93 \times 77.3) - ((1.42 \times (77.3)^2)/22.7)] &= -111. \end{aligned}$$

$$\text{Heat of liquid .776 lbs. of ammonia at } 21^\circ = \underline{-12.1}$$

$$\begin{aligned} \text{Total heat of liquids after passing through} & \\ \text{expansion valve} &= 14.04 \text{ B.t.u.} \end{aligned}$$

$$\text{Total heat should equal} = \underline{107.6} \quad ``$$

$$\text{Difference} = 93.56 \text{ B.t.u.}$$

Since the latent heat of ammonia at 21° is 552.2 B.t.u. per pound, .168 lbs. of ammonia must have been vaporized in order to make up this difference.

There remains in the expansion coils, therefore,

$$\text{Lbs. of liquor at 73 percent} = .3504$$

$$\text{Lbs. of ammonia vapor} = .168$$

$$\text{Lbs. of liquid ammonia} = .608$$

The refrigerating effect, instead of corresponding to the evaporation of one pound of ammonia is reduced due to the presence of the water to only the equivalent of .608 lbs. of ammonia. Therefore, per pound of ammonia is circulated, there is only $552.2 \times .608 = 335$ B.t.u. refrigerating effect.

COOLING WATER NECESSARY FOR ABSORBER

The liquid and vapors left in the absorber must be cooled from 300° to 82 ½°.

The heat content at 300° was = 300.65 B.t.u.

The liquor and vapor from the expansion coils has a heat content of 107.6 + 335 = 442.6 ``

Total = 743.25 B.t.u.

After absorption, the heat content is = -170.03 ``

Therefore, the cooling water must have removed 913.28 B.t.u.

SUMMARY OF B.T.U. USED IN HEATING AND COOLING THE MEDIUM.

Lbs. of ammonia Circulated	1 lb	In order to obtain a refrigerating effect of 167 lbs. of ice in 24 hrs. 72 lbs.
Heat required during generating period	1276.54 B.t.u.	91,100 B.t.u.
Heat removed in condenser by cooling water	698.4 B.t.u.	50,000 B.t.u.
Refrigerating effect	335. B.t.u.	24,000 B.t.u.
Heat removed in absorber by cooling water	913.28 B.t.u.	65,600 B.t.u.

1611.54 1611.68

CHECK

The foregoing table shows that in order to equal the rating of the Fort Wayne type OC-2 machine, it would be necessary to circulate 72 lbs. of ammonia in twenty-four hours.

This would require a heating of 91,100 B.t.u., or 26.3 KW-hours, and would require a cooling of 115,600 B.t.u. or 461 gallons of cooling water raised thirty degrees.

On the other hand, only about 50 lbs. of ice per twenty-four hours is required. For this condition, there must be circulated each day 21.6 lbs. of ammonia; 8 KW-hours energy would be consumed and 139 gallons of water would be raised thirty degrees. If this were accomplished in six operations, there would be required per operation 3.6 lbs. of ammonia, 1.34 KW-hours, and 2.22 gallons of water.

The catalogue of the Keith Electric Refrigerator states that their machine requires approximately 70 KW-hours per month, which is very much better than the theoretical performance given above. The theoretical performance can be improved by only heating to approximately 230°, in which case so much water vapor would not be boiled over. The catalogue of this machine also shows a pre-cooler which would condense out some of the water vapor between the generator and the condenser. It can be noted that one of the great causes of inefficiency in the above theoretical cycle is due to the water vapor boiled over with the ammonia.

If the boiling operation is only carried to 230° only 819.39 B.t.u. will be required to heat the medium in the generator.

There will be boiled over into the condenser #

Foot-note (#): There will be left in the generator liquor and vapors having a total heat of 179.5 B.t.u. and only .692 lbs. of ammonia will be circulated.

-20-

.692 lbs. ammonia vapor at 622 B.t.u.	=	430
.035422 lbs. steam at 1140 B.t.u.	=	<u>40</u>
Total heat of vapors going to condenser	=	470 B.t.u.

These vapors must be cooled to 82.5° and liquefied.

The possible concentration is 77.3 percent.

After liquefaction, there will be .035422 lbs. of water which can take up .12 lbs. of ammonia, making .155422 lbs. of liquor at 77.3 percent concentration. This leaves .572 lbs. of liquid ammonia.

$$\text{Heat of liquid of .155422 lbs. of liquor at } 82.5^\circ = .55422 (82.5 - 32) = 7.9 \text{ B.t.u.}$$

$$\text{Heat of absorbed vapor, } (.155422 \times .773 \times 514.7) = 62.0 \text{ ``}$$

$$\text{Heat of partial absorption of liquor} = .155422 [8.93 \times 77.3 - ((1.42 \times (77.3)^2)/22.7)] = -49.4 \text{ ``}$$

$$\text{Heat of .572 lbs. of liquid ammonia} = \underline{32.5 \text{ ``}}$$

$$\text{Total heat of liquids leaving condenser} = 53.0 \text{ ``}$$

$$\text{Total heat of vapors entering condenser} = \underline{470.0 \text{ ``}}$$

$$\text{Cooling water must absorb} \quad 417.0 \text{ B.t.u.}$$

Going through the expansion valve, the total heat stays constant.

At 21° F. and 49.28 lbs., the concentration will be 73 percent.

Therefore, .025 lbs. of ammonia will be forced out of the solution. This leaves .130422 lbs. of liquor and .597 lbs. of ammonia.

Heat of .130422 lbs. of liquor	=	-1.07 B.t.u.
Heat of absorbed vapor	=	52.1 ``
Heat of partial absorption	=	-41.4 ``
Heat of liquid of .597 lbs. of ammonia	=	<u>- 9.3 ``</u>
Total	=	0.33 B.t.u.
Heat should equal	=	<u>+ 53.00 ``</u>
Heat corresponding to evaporation	=	52.67 B.t.u.

Therefore, .095 lbs. of ammonia must be vaporized.

There remain in the expansion coils.

Lbs. of liquor at 75%	.130422
Lbs. of ammonia vapor	.095
Lbs of liquid ammonia	.502

The refrigerating effect instead of corresponding to .692 lbs. of ammonia will only be the equivalent of .502 lbs., or 278 B.t.u.

Heat content left in the generator	=	179.5 B.t.u.
Heat from expansion coils	=	331.0 ``
Heat from absorption	=	<u>-170.03 ``</u>
Heat removed by cooling water	=	680.53 B.t.u.

SUMMARY

Lbs. of ammonia Circulated	.692 lbs.	In order to obtain a refrigerating effect of 50 lbs. of ice in 24 hours 18 lbs.
Heat required during Generating period	819.39 B.t.u.	21,300 B.t.u.
Heat removed in con- denser by cooling water	417 B.t.u.	10,850 B.t.u.
Refrigerating effect	278. B.t.u.	7,200 B.t.u.
Heat removed in absorber By cooling water	680.53 B.t.u.	17,800 B.t.u.
	1097.39	1097.53

CHECK

Therefore, in order to give the equivalent
of 50 lbs. of ice in twenty-four hours,
18 lbs. ammonia circulated
6.15 KW-hours electricity
71 gallons of water

By means of a pre-cooler, the electric power
could not possibly be reduced to less than approximately
4 ½ KW-hours, which would be 134 KW-hours per month.

(EDITOR'S NOTE: Page 23 is missing)

Professor Keyes, of Massachusetts Institute of Technology, has invented an absorption machine with a solid absorbent, in which case no water vapor would be boiled over. Professor Keyes has not revealed what the solid absorbent is and, therefore, the heats of absorption are unknown.

Assume that the heat of absorption in the solid absorbent of Professor Keyes' machine is the same as the heat of absorption in water.

Since the machine cannot boil over in steam, approximately 178.76 B.t.u. might be saved during the generation period.

The total heat of ammonia vapor going to the condenser would be 637 B.t.u.

The liquid ammonia leaving the condenser at 82.5° F. would have a total heat of 56.9 B.t.u. Therefore, the cooling water must remove 580.1 B.t.u.

In going through the expansion valve, the heat content must remain constant, or 56.9 B.t.u. The heat of one pound of liquid at 21° is minus 12.1 B.t.u. Therefore, going through the expansion valve, .124 lbs. of ammonia vapor would be vaporized in order to produce 69 B.t.u. This would leave .876 lbs. of liquid in the expansion coils, from which the refrigerating effect of 480 B.t.u. could be obtained.

Again, the total heat in the absorber would be approximately	=	300.65 B.t.u
The total heat of the refrigerant entering the absorber from the expansion coils	=	536.9 ``
After absorption, the total heat in the absorber	=	-170.03 ``
The B.t.u. abstracted by the cooling water in the absorber must therefore be	=	1007.58 B.t.u.

Lbs. of ammonia circulated	1 lb.	In order to obtain a rating of 50 lbs. of ice in 24 hours. 15 lbs.
Heat required during generating period	1097.78 B.t.u.	16,400 B.t.u.
Heat removed in condenser by cooling water	580.1 B.t.u.	8,700 B.t.u.
Refrigerating effect	480 B.t.u.	7,200 B.t.u.
Heat removed in absorber by cooling water	1007 B.t.u.	16,000 B.t.u.
	1577.78	1587.1

NEARLY CHECKS

Therefore, with Professor Keyes' machine, in order to obtain a refrigerating effect of 50 lbs. of ice in twenty-four hours, 15 lbs. of ammonia must be circulated, 4.8 KW-hours heating would be required, and 64 gallons of water would be raised thirty degrees.

It would probably be wise to add about 20 per cent for radiation and the heat required to heat and cool the container. The daily input in electric power and water would be 5.8 KW-hours and 77 gallons.

If the generator operates half of the time, a 485 watt unit would be required.

Professor Keyes' machine has a 500 watt unit and takes about 72 gallons of water a day. However, the daily energy consumption is given as only 3 KW-hours a day.

APPENDIX #11.

COMPARISON OF VARIOUS REFRIGERANTS

Mr. Grant, president of the Delco Light Company told me that they had investigated six hundred refrigerants and had finally decided on sulphur dioxide as the best one for their Frigidaire machine. In preparing this report, I have not had time to investigate six hundred refrigerants, but have made a comparison of about eight of the more popular vapors.

For a machine with internal lubrication like the Frigidaire or our Fort Wayne type OC-2 machine, the indications are that sulphur dioxide is probably the best refrigerant for the following reasons:

- a- It will not dissolve the oil.
- b- Its coefficient of performance is nearly as high as ammonia
- c- The pressures are lower than ammonia.
- d- It is absolutely non-explosive.
- e- It is less poisonous than ammonia.

The disadvantages are:

- a- It has a more immediate effect on the nose and throat than ammonia.
- b- In the presence of water vapor, it forms sulphurous acid.
- c- The pressures are higher than with ethyl chloride or butane.

- d- The coefficient of performance is less than ethyl chloride or butane.

For a machine where there is no internal lubrication such as the Savage Arms mercury pump, ethyl chloride is probably the best refrigerant. Its advantages are:

- a- High coefficient of performance.
- b- Low pressure.
- c- Non-poisonous, although narcotic.
- d- Less explosive than butane.
- e- Perhaps better known than butane.

Its disadvantages are:

- a- More explosive than ammonia.

Comparison with Illuminating Gas

There is no more reason to be afraid of any of these refrigerants than of illuminating gas because,

- a- If illuminating gas contains carbon monoxide it is poisonous. One part by volume of carbon monoxide in eight hundred parts of air will produce death.
- b- Illuminating gas is explosive. Nice parts of "water gas" in one hundred parts of air will produce an explosive mixture. Six parts of "coal gas" and one hundred parts of air will make an explosive mixture.

The violence of an air-illuminating gas explosion would equal that of

pentane, butane, methane, or propane, and would exceed in violence the explosion of ethyl chloride or methyl chloride mixed with air.

The maximum explosive pressure of illuminating gas might be 75 lbs. per square inch.

These recommendations are based on the following detailed comparison of these various refrigerants.

1. Thermodynamic Comparison

If the refrigerating machine operated in accordance with a true Carnet cycle, the efficiency would be independent of the medium, but since in almost all cases the liquid is expanded through a throttle valve instead of an expansion engine, the cycle is not reversible. There is a loss in refrigerating effect due to the evaporation of some of the liquid while passing through the expansion valve. The amount of air loss for different refrigerants is approximately proportional to the ratio of the heat lost in cooling the liquid from the temperature of the condenser to the temperature of the expansion coils, to the latent heat of evaporation.

The following table shows the comparison of the theoretical coefficients of performance for various refrigerants operating between 82 ½ degrees Fahrenheit condenser temperature and 21 degrees Fahrenheit expansion

coil temperature. The coefficient of performance is the ratio of the refrigerating effect divided by the required mechanical energy expressed in B.t.u.

These coefficients of performance are obtained from the attached temperature-entropy charts.

a- H-99386 represents the temperature-entropy chart for ammonia with wet compression and H-99385 represents the temperature-entropy diagram for ammonia with dry compression. The figures for these charts are made up with the use of table in G.A. Goodenough's "Properties of Steam and Ammonia".

b- H-99384 represents the temperature-entropy diagram for wet compression of sulphur dioxide and H-99383 represents the temperature-entropy diagram of dry compression of sulphur dioxide. These were drawn from the data given in the "Steam and Entropy Tables" by Cecil M. Peabody. The data for the super-heated sulphur dioxide vapor is calculated using the value of specific heat at constant pressure determined by Rognault, .15438, in the equation,

$$\text{Entropy} = C_p \log_e (T/T_1)$$

c- H-99387 represents wet compression for carbon dioxide and H-99388 represents dry compression of carbon dioxide. These were plotted from the tables on

pages 388 and 389 of A. M. Greene, Jr's, "Elements of Refrigeration".

d- H-99389 represents wet compression and H-99390 represents dry compression of methyl chloride. These diagrams were plotted from the data given on pages 15 through 18 of the April, 1923, Refrigerating World, from an article, "Properties of Methyl Chloride", by Charles H. Herter.

e- H-99391 represents wet compression and H-99392 represents dry compression of ethyl chloride. These curves were plotted from data given on page 14 of the August, 1922, Refrigerating World, from an article, "Ethyl Chloride", by Charles H. Herter. The properties of super-heated ethyl chloride were estimated from Regnault's value of a specific heat at constant pressure of .274.

f- H-99393 represents wet compression of pentane. These were drawn from the data on pages 954 and 955 of the December 12, 1922, issue of Power, "Low Pressure Refrigerants", by Harry D. Edwards. The data given in this article was not in the proper form and it was necessary to estimate the specific heat of the liquid from a value of the heat of liquid at 80 degrees Fahrenheit above 32 degrees, which was given in one of the tables. Apparently,

$$c = .3$$

The entropy of the liquid was calculated with this specific heat, and the entropy of vaporization was calculated from

the values of latent heat of vaporization given in the tables.

I could not draw the curves for dry compression because I could not find a value of the specific heat of the super-heated vapor.

g- H-99394 represents wet compression of butane and is calculated from the same article, "Low Pressure Refrigerants", by Harry D. Edwards, referred to Above. Apparently the specific heat of liquid butane is the same as pentane, namely, $C = .3$

h- I could not find sufficiently complete data on methane to make similar calculations.

Professor Keyes of Massachusetts Institute of Technology has made some investigations on methane and it might be possible to obtain some data from him.

i- I have not obtained sufficient data on propane to make similar calculations. Propane is being exploited commercially by the Carr Lighting and Power Company, Adams Building, 61 Broadway, New York City, but the pamphlet which they publish does not give very much scientific information.

Table #
 THERMODYNAMIC CHARACTERISTICS OF REFRIGERANTS
 BETWEEN 21°F. and 82 ½ °F.

	CAR- NOT	AMMONIA		SULPHUR DIOXIDE		CARBON DIOXIDE	
		Wet	Dry	Wet	Dry	Wet	Dry
Refrigerating Effect per lb.		438.	483.2	142.5	154.2	31.	61.3
Energy required		58.25	71.	20.	22.15	9.6	14.9
Theoretical coeffi cient of performance	7.81	7.5	6.8	7.11	6.96	3.24	4.11
Lbs. circulated per 1000 B.t.u.		2.28	2.07	7.04	6.5	32.3	16.4
Cu. Ft. circulated per 1000 B.t.u.		12.1	12.	31.3	30	4.69	3.32
Condenser gauge pressure		145.	145.	48.	48.	977.3	977.3
Suction gauge pressure		34.6	34.6	2.88	2.88	413.7	413.7

METHYL CHLORIDE		ETHYL CHLORIDE		PENTANE		BUTANE		METHANE	PROPANE
Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry		
142.54	147.36	144.	148.4	138.5		136.			
21.3	21.89	19.5	20.77	19.		18.5			
6.71	6.75	7.38	7.17	7.3		7.38			
7.03	6.8	6.97	6.75	7.22		7.39			
22.6	22.4	80.	79.2	158.		54.5			
75.78	75.78	11.	11.	-3.6		31.6		138.	
14.73	14.73	-7.7	-7.7	-12.		.2		43.1	

The above table would seem to indicate that from the standpoint of thermodynamic efficiency, the two best refrigerants are ethyl chloride and butane.

2. Mechanical Comparison

Under this heading, there are three questions being considered.

a. Pressure

Due to the high pressure, I believe carbon dioxide should not be considered. Ammonia and propane also run at rather high pressures.

If the machine has a stuffing box, negative pressures should be avoided, but with a sealed system I do not consider negative pressures a disadvantage.

b. Volume

Theoretically, there should be no mechanical preference as to whether large volumes at low pressures or small volumes at high pressures are pumped. Practically, it is difficult to make very small volume compressors and, therefore, for domestic machines I should favor the larger volume refrigerants. However, it will be found that the most convenient volume depends largely on the ??? of pump.

c. Lubrication

All of these refrigerants except ammonia,

carbon dioxide, and sulphur dioxide have a tendency to dissolve the oil. Therefore, if there is internal lubrication, sulphur dioxide has the advantage. If there is no internal lubrication, either ethyl chloride or butane should be used.

3. Chemical Properties

The following table gives some of the chemical properties.

-10-

TABLE #

NUMBER OF POUNDS OF REFRIGERANT WHICH RELEASED IN A ROOM
6' x 10' x 10' WOULD BE EITHER POISONOUS OR EXPLOSIVE

	Ammonia	Sulphur Dioxide	Carbon Dioxide	Methyl Chloride	Ethyl Chloride	Pentane	Butane	Methane	Propane
Dangerous if in- haled for some time	.125	.168		.06(*)	.06(*)	3	3	3	
Immediate effect on nose and throat	.375	.002							
Poisonous effect after burning				.003	.003				
Explosive or not	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Amount to form explosive mixture	67#			84#	8#				

Foot-note (*): These gases are narcotic rather than poisonous.

a. Poisonous

It can be seen that ethyl and methyl chloride are very much less poisonous than either ammonia or sulphur dioxide. In fact, they are only narcotic except after burning.

The hydrocarbon gases, pentane, butane, and methane, are more like gasoline fumes and are not nearly as poisonous.

b. Explosiveness

From this standpoint, sulphur dioxide is the best, because it will not explode under any condition. Ethyl chloride is bad because eight pounds in a small room would form an explosive mixture. I understand that the Coldak machine has twelve and a half pounds of ethyl chloride in it.

The hydrocarbon gases, pentane, butane, and methane, would be more violent in their explosion than ethyl chloride. I could get no figures as to the quantities necessary to form explosive mixtures.

c. Corrosive Effect

Sulphur dioxide will form sulphurous acid if released in a damp atmosphere, and this will have a corrosive effect.

The figures on the poisonous qualities of these gases and of the amounts necessary to form explosive

mixtures are calculated from information obtained from Professor Ellery of Union College, and Mr. Dansizen of the Research Laboratory.

4. Cost Comparison The purchasing agent of the Fort Wayne Works obtained the following quotations on several of these refrigerants:

	<u>Cost in cents per lb.</u>
Sulphur Dioxide	9 ½ ¢
Ammonia	38 ¢
Ethyl Chloride	32 ¢
Methyl Chloride	¢

It might be thought that for true comparison these costs should be multiplied by the number of pounds shown in the fourth line of the table on page seven. But the total number of pounds refrigerant in a system depends more on the design of the evaporation coils than the thermodynamic properties. For instance the Fort Wayne type OC-2 machine contains between 3 & 4 pounds of sulphur dioxide and the Coldak contains between 8 & 12 pounds of ethyl chloride. We can see no very good reason why an ethyl chloride machine should contain more pounds of refrigerant than a sulphur dioxide machine. Perhaps the Coldak Company uses so much ethyl chloride that any leakage there may be through the stuffing box will be a smaller percentage of the whole. The Fort Wayne type OC-2 is a completely sealed machine and therefore no allowance is necessary for leakage.

Apparently sulphur dioxide is the least expensive refrigerant for small machines.

It is likely that in large machines three times as much SO₂ would be required as ammonia and this would make the total cost about the same.

(Editors Note: 32 PAGES OF DIAGRAMS are too faded to be included)

“A refrigerator is of little value which will not operate with reasonable care and ice consumption at 45 degrees Fahrenheit during the summer months.”

The following is copied from the last page of the bulletin gotten out by the Frigidor Corporation:

MILK TEST

In an average room.

In an average refrigerator.

At a very low temperature such as in not possible to obtain under the usual conditions in an ice-cooled system, but is a regularly present in the Frigidor system.

NUMBER OF BACTERIA PER CUBIC CENTIMETER# IN CERTIFIED MILK HELD AT DIFFERENT TEMPERATURES

Approximate Number of Living Bacteria at Following Temperatures

Days Held	Room Temperature 68° F	Average Refrigerator 54° F	Days Held	Frigidor Temperature 33° F
Fresh	3,000 sweet	3,000 sweet	Fresh	2,900 sweet
1	1,500,000 “	8,000 “	1-8 days	2800 to 3,100 “
2	31,000,000 “	150,000 “	9 “	22,000 “
3	300,000,000 sour	2,300,000 “	10 “	200,000 “
4	***** “	125,000,000 “	/ 11 “	1?,000,000 “
5	***** “	500,000,000 sour		

(#): About a quarter of a teaspoonful.

(/): End of experiment with milk still sweet.

It will be seen that the numbers of bacteria in the milk after two (2) days of the average refrigerator

temperature were larger than they were at the refrigerator temperature after nine (9) days. Poorer grades of milk would show far less satisfactory results for the ice cooling system.

I wrote the State Board of Health for their opinion on the proper temperature and humidity for domestic ice machines. They had no such data and forwarded my letter to the Department of Farms and Markets. The Department of Farms and Markets had no data on this subject, and at their suggestion I wrote the Department of Penology at Cornell University. The Department of Penology replied giving a number of figures which applied to cold storage warehouse where food is kept for months or years. They forwarded my letter to the Department of Dairy Industry, Cornell University, seemed to fool that milk and butter could be kept satisfactorily for a few weeks with temperatures of from forty to fifty degrees Fahrenheit.

f. In traveling around the country, I find that most of the people who have investigated domestic refrigeration feel that the temperature in the food compartment should be below 45° F. and, as a factor of safety, try to obtain a temperature of 40° .

The temperatures obtained in this average box are over 45° on a 70 degree day, and as high as 58° on a 90 degree day.

g. How can an average temperature of 40° be obtained in the food compartment of this box by melting ice?

On pages 14 and 15 of "Elements of Refrigeration", by Professor A. M. Greene, Jr., curves are given showing the temperatures which can be obtained by mixing salt and water. Apparently, a temperature of minus 10° F. can be obtained by mixing one-quarter of a pound of salt with three-quarters of a pound of ice. It is my understanding that Professor Greene's tables are copied from Bulletin No. 98 of the United States Department of Agriculture.

Assume that the temperature of the ice in the refrigerator can be lowered by the above method. Line four of the table shows the ice temperature which would have to be obtained to hold the box at 40° on a 70 degree day. The calculations are as follows.

The temperature difference between the food and the outside air would be thirty degrees. Assuming that the best heat transmission is directly proportional, 1.28 lbs. of ice would be melted.

In a similar manner, it can be calculated that the ice must be minus 9° F. in order to maintain the food compartment at 40°, with a room temperature of 90°.

g. Curves H-99367 illustrate graphically the data in lines 1,2,3,4, and 5 of the table. It seems evident that the air passages in the ice box are too restricted. This box could probably be greatly improved by enlarging them. It would be difficult to state

theoretically just how much could be accomplished in this way.

i. One very obvious way of improving the box would be to increase the insulation.

If the ice is 32° F. and the food compartment is 40° F., the heat transfer between them by equation (3) is 0.8 lbs.

In order that a meltage of 0.8 lbs. May maintain a difference of 30 degrees between the food compartment and the outside air, the insulation must be increased so that only .0905 B.t.u. will flow per square foot, per hour, per degree. The reciprocals of the conductivity can be treated as resistance. The additional resistance required is the difference between the total required resistance and the present resistance.

$$(1/.0905) - (1/.143) = (1/25)$$

Therefore, the additional insulation must have a conductivity of less than .25 B.t.u. per square foot, per hour, per degree.

Non-Pareil corkboard, 1" thick has a conductivity of .25 B.t.u. per hour, per square foot, per degree.

Therefore, the additional insulation should consist of 1" Non-Pareil corkboard. The price of this is

about $7\frac{3}{4}$ cents per board-foot. Therefore, $42\frac{1}{2}$ board-feet would cost \$3.30. Double this to cover the labor of installing it, and multiply by three to cover commercial percentages. This shows that this extra inch of cork insulation could have been furnished with box at an additional selling price of about \$20.00.

Assuming 6 percent interest on the investment and 10 percent depreciation, it is found that the annual cost is \$3.00.

On the other hand, better refrigeration is assured and 0.26 lbs. Of ice per hour is saved. This is 6.25 lbs. per day. Assuming that the box is used during six months of the year, the annual saving is 1140 lbs., or $11\frac{1}{2}$ hundred-weight. At 60 cents per hundred-weight, this corresponds to a saving of \$6.85 worth of ice, or a net saving of \$3.65. This is 18 percent on the investment as well as better refrigeration. On a 90 degree day, this box would melt 1.12 lbs. of ice and the food compartment would rise to 48° .

If it is desired to keep the box at 40° with a room temperature of 90 degrees, the conductivity of the insulation must be resized to .054.

$$(1/.054) - (1/.143) = (1/.087)$$

Therefore, the additional insulation must have a conductivity of less than .087 B.t.u. per square feet, per hour, per degree. This would require about 3” of Non-Pareil corkboard.

The interest and depreciation on this would be \$10.95.

This box under average 70 degree conditions would only melt .55 lbs. of ice per hour and the temperature of the food compartment would be about 34 ½ degrees. There would be a saving of .51 lbs. per hour, or 2240 lbs. during the six warmer months. At 60 cents per hundred-weight, this would be \$13.50 gross saving. The not saving would be \$2.55, which is 4 ¼ percent profit on the \$60.00 additional investment.

j. The curves on H-99368 show graphically the effect which additional insulation has on the food compartment temperatures and the rates of ice meltage.

k. Dr. John R. Williams in his paper before the Third International Congress on Refrigeration, in 1913, takes up the question of the economy which can be obtained by adding extra cork insulation in the refrigerator. The following conclusions are quoted from this paper:

“Neither the cellar nor pantry in the home are efficiently cold to keep perishable foods from spoiling during the warm months of the year; therefore, every home should have a good refrigerator.

“Only about half the homes in the city have refrigerators; the other half are compelled to depend upon the inadequate protection afforded by the cellar.

“The majority of domestic refrigerators are inefficient because they consume too much ice and do not maintain a temperature low enough to prevent food from spoiling.

“The chief explanation of their inefficiency is to be found in the lack of sufficient and proper installation.

“There are a large number of shoddy refrigerators on the market which contain no other insulation than a sheet or two of paper. They are sold chiefly to working people who can ill afford to use them, because they are both unsanitary and grossly uneconomical in the consumption of ice.

“The waste from ice meltage because of improper insulation of refrigerators in Rochester house (population of city, 880,000) amounts to 60,000 tons yearly, or about \$380,000.

“At least \$100,000. more is wasted yearly in the present competitive system of delivery. #

“Unnecessary waste is now making refrigeration cost consumers from three to five times as much as it should.

“There are certain simple directions which will be of assistance in selecting a refrigerator. If they are observed, the purchaser can at least Avoid being defrauded.

“One should insist upon seeing a section of the wall of the refrigerator which he contemplates buying. Honest manufacturers are always will to let customers know the character of their wares.

“Do not buy a box which does not bear the name and address of the maker, nor one

Foot-note: See last page of appendix #4 for cost of delivery.

sold only under the name of a retail dealer. If the manufacturer is ashamed to acknowledge his handiwork, you are justified in suspecting fraud.

“Do not buy a box which contains less than three inches of good insulation, not including the wooden case or the metal or tile lining.

“Beware of impossible “vacuum”, doubtful “dead air space”, and no-good paper insulation.

“Money invested in insulation will be returned many times in the saving in ice bills. Added insulation mean not only economy in ice Consumption, but also lower temperatures in the Refrigerator and the less spoiling of food.”

Mr. F. Nichols of Pittsburgh, Pa., presented a paper at the joint meeting of the A.S.R.E. and the A.S. M.E., December 4, 1922, entitled, “The Economic Thickness of Insulation in the Refrigerating Field”. Mr. Nichols has made up a general formula for the most economic thickness of insulation, based on interest and depreciation on investment, and operating costs.

3. Value of Baffles

It is an interesting question as to why ice boxes are made with air circulation to a separate ice compartment, instead of putting the ice in the food compartment. Experiments with our Fort Wayne type OC-2 machine in a Jewett box show that better temperatures can be obtained, when the baffles are removed, by direct radiation and con-

duction from the brine tank to the food. Why do not ice box builders do the same thing? One possible advantage of the air circulation method may be evident from the following hypothetical operation of the ice box.

- a. Warm air enters the food compartment when the door is opened.
- b. The warm air is convected to the ice compartment where it is chilled, and any excess moisture condensed out.
- c. The air passing from the ice compartment to the food compartment warms up slightly, which decreases the humidity.

Thus, it is seen that even with an ice box there is a theoretical possibility of obtaining dry refrigeration by means of air circulation.

On the other hand, if the ice were in the same compartment with the food, any moisture condensing the air might fall in the form of a mist or dew on the food, making it soggy.

General Electric Company
Internal Correspondence

Subject: REPORT ON DOMESTIC REFRIGERATING MACHINES.

Location:

Referring to:

Schenectady, Sept. 20, 1923.

Publication Department,

Building #2.

Will you please insert the following note in your copy of the report on "Domestic Refrigerating Machines" appendix #12, "Balsa Boxes".

I have just learned confidentially that there has been trouble with some of the cement lined ice boxes made by the American Balsa Company, due to the Balsa wood warping and cracking the cement. It is therefore necessary for us to withdraw our approval of this box. If the General Electric Company decides to go into domestic refrigerating machine business, it will probably be necessary to make a little further study of the refrigerator box problem.

At note of this should be made in paragraph #3, on page 10, Report #1, "Summary and Conclusions".

A. R. STEVENSON, JR.
CONSULTING ENGR. DEPT.

ARS;DW

APPENDIX # 12

BALSA REFRIGERATOR BOX

- (1) Name of manufacturer – American Balsa Company, Inc/
- (2) Address – 152nd & Exterior Sts., New York City, N.Y.
- (3) Resources – This company is financed by the American International Corporation.

The box has the following dimensions:

	<u>High</u>	<u>Wide</u>	<u>Deep</u>
Outside dimensions - - - - -	50"	35 1/2"	21"
Food compartment - - - - -	38 5/8"	16"	15 5/8"
Milk compartment - - - - -	11 5/8"	13"	15 5/8"
Ice compartment# - - - - -	27"	14 1/8"	15 5/8"

	<u>Cubical content in cu. Ft.</u>
Total inside - - - - -	10.53
Ice chamber - - - - -	3.45
Food & milk compartments-	7.08

A ninety-six hour test was run on this box with a 70°F. room temperatures. The average temperature in the food compartment was 44 degrees Fah., and the average ice meltage was .802 lbs. per hour.

The box is constructed of two inches of Balsa wood, dovetailed together, forming both the framework and the insulation. (Balsa wood has the same insulation resistance as cork.)

This Balsa insulation is lined inside and out with 5/16" of artificial stone, made from a special waterproofed composition with mangasite as the base. (This is the same composition that is used in the floors of subway cars, except that it is given an additional waterproofing treatment."

The box is completely covered with white enamel

Foot-note (#): The ice compartment is apparently large enough to accommodate the brine tank of the type OC-2 machine.

Balsa - #2

paint both inside and out.

The box sells at retail for \$104.00. I understand from one of their employees that the factory cost is \$80.00. I believe that we might buy these boxes for \$90.00 in lots of one hundred, arranged for the reception of the type OC-2 machine.

The rating of a machine suitable for use with this Balsa Box could be estimated as follows:

The total outside area of the box is 49.6 sq. ft.

There are two inches of Balsa wood insulation and 5/8" of artificial stone.

According to a paper by H. C. Dickinson and M. S. Van Dusen, of the National Bureau of Standards, reprinted in the American Society of Refrigerating Engineers Journal, September 1916, the Balsa wood has a coefficient of heat transmission 12-1/2 per cent greater than cork. In the same paper the average coefficient of heat transmission for brick or cement is about sixteen times as great as that of cork. We have assumed that this figure can be used for the mangasite artificial stone. The insulation is therefore equivalent to

2" Balsa wood equivalent to	1.78" cork
5/8" mangasite " "	$\frac{.04}{1.82}$ "
Total insulation	1.82"

x Total air film (inside and out)	
Equivalent to	$\frac{.5}{2.32}$ "

Ø B.t.u. per hour per sq. ft. per degree is .1325

x(Foot Note) See pages 8 and 9 of appendix #6 where it was calculated that a flow of 152 B.t.u. per hour through a surface of 42.5 sq. ft. made an air film drop of 2.9°F. (Average of 3.2° and 2.6° calculated by different methods). The total drop inside and out would be double this, or 5.8°F. Since 3.58 B.t.u. per hour per sq. ft. cause a drop of 5.6° the two air films have a coefficient of heat transmission of .618 which is equivalent to 1/2" of cork.

Ø (Foot Note) The coefficient of heat transmission of cork is .308 B.t.u. per hour per sq. ft. per degree per inch of thickness, according to the same paper by Mesars. Dickinson and Van Dusen.

Balsa - #3.

For a 26° drop B.t.u. per sq. ft. per hour equals 3.45

For an area of 49.6 sq. ft. equals 171 B.t.u.

This is equivalent in pounds of ice per hour to 1.19.

The American Balsa Company claim to have made a test which indicated an ice meltage of .802 pounds of ice per hour. This is 32.5 percent better than the above estimated figure. In order to justify this test it would be necessary to assume that either the Balsa wood or the magnesite has a much lower coefficient of heat transfer than we estimated.

In making a conservation decision as to the proper rating for a machine to refrigerate this box we have used our own theoretical figures rather than the test made by the American Balsa Company.

AVERAGE LOAD. (See page 4 Report #7)

	<u>Pounds ice per 24 hours</u>
To hold box at 40° with room at 70°	33
To freeze 12-1/2# ice once in 24 hours	15.7
To cool food once in 24 hours	2.35
Opening box 25 times	<u>.82</u>
	51.87

The Fort Wayne type OC-2, form G, air cooled machine could easily carry this load with a brine temperature of about 23°F.

MAXIMUM LOAD (See page 3 Report #7)

	<u>Rate pounds ice per hour</u>
To hold box at 44° with room at 90°	2.11
To freeze 12-1/2# ice in 24 hours	.69
To cool food in three hours	1.06
Opening box four times per hour	<u>.47</u>
	4.33

Which is a rate of refrigeration equal to 104 pounds of ice per day.

In redesigning the OC machine for air cooled operation with this box, a capacity of at least 106 pounds of ice per 24 hours with 26° brine and 90° room temperature should be maintained.

APPENDIX #12-A

INFORMATION FURNISHED BY MR. STUART OTTO
ON BALSA BOX

Mr. Stuart Otto told me that he has several of the Balsa boxes in his factory and that the Balsa wood had the following defects:

- 1- The Balsa wood did not have the qualities claimed for it.
- 2- The magnesite covering cracked off.
- 3- The white enamel paint would not stick properly to the magnesite.

ARStevenson, Jr-DW

February 19, 1924

APPENDIX 13

TYPE OC-2 MACHINE

- (1) Name of manufacturer – General Electric Company.
- (2) Address- Fort Wayne, Indiana.

It does not seem advisable to repeat the very thorough description of this machine which was given in Mr. Hunting's report of January 31, 1922. I will merely mention that the following changes have been made since that time.

Considerable trouble was found with the gearing and, therefore, the slow speed, two cylinder double acting compressor was abandoned and replaced with a high speed, two cylinder single acting compressor, direct connected to the motor. One of these machines has been in operation in Mr. Waters' house for the last few months and the performance has apparently been very satisfactory.

It is recommended that before this machine be put on the market, it be changed for air cooling by making a condenser consisting of approximately 245 feet of copper tubing, coiled around the outside of the casing, with an air space of about two inches between it and this casing. The water jacket should be removed and the motor housing cast with fins for air cooling.

The chief advantages of this machine are:

- a- The motor is included inside the gas compartment, which eliminates the problem of a stuffing box.
- b- The machine is made as a complete unit, so that no piping connections will have to be made in the field. The field service will be purely adjusting the electrical control apparatus and in case anything serious goes wrong inside the machine, it will be returned to the factory for repairs.

The machine could probably be put on the market at a price of \$593.00. (See Part III of Report #2. Manufacturing and Financial.) The machine as present takes about .315 watt-hours per B.t.u. Then redesigned for

Foot-note (#): An abstract from Mr. Hunting's report is included in appendix #69.

Type OC-2 - #2

air cooling, it would probably take about 9 percent more power.

Considerable further technical information can be found on the type OC-2 machine by referring to appendix # 9. "Discussion of the Possible Redesign of the Fort Wayne Type OC-2 Machine for Air Cooling", and appendix # 7. "Factors Which Influence the Rating of a Domestic Refrigerating Machine".

Special reports are included on the machines installed outside of Fort Wayne and Schenectady, as follows:

G. A. Hughes, Chicago, Illinois.
New York Office, General Electric Company.
W. J. Hanley, Knightstown, Indiana.
M. Griswold, Erie Pennsylvania.
City Ice & Fuel Company, Cleveland, Ohio.

These machine are especially interesting because they were at a distance from a service man.

CITY ICE & FUEL CO., CLEVELAND, OHIO.

Type OC-2, Form F Refrigerating Machine #10027,
Installed July 16, 1922.

Operated until Aug. 2, 1922. Machine was unreliable, and would not always start automatically. It was returned to the factory and opened and it was found that the trouble was due to varnish coming off the stator and equipped with an untreated stator. Operation O.K.

In the meantime this machine was replaced at
Cleveland, by:

Type OC-2, Form F Refrigerating Machine #10043.

Installed Aug. 6, 1922. March 18, 1922. Overload device stopped the machine. Machine was started on March 19, 1922, by pressing in the reset button. This was probably due to trouble on the power lines. Operated in a satisfactory manner and without other adjustment until April 18, 1922, when it was decided to discontinue the installation as it had served its purpose. The machine was still in operative condition.

When returned to the factory the machine was found to be in operative condition, and no adjustments were necessary. The machine was then shipped to Cak Pork, Ill. To be installed in the residence of Mr. S.H. Neiler. Shipment has not yet been received at Cak Park.

C. A. HUGHES, -EDISON ELECTRIC APP. CO., CHICAGO, ILL.

Type OC-2, Form E Refrigerating Machine #10023.

Installed in the showrooms of the Edison Electric Appliance Co., Chicago, Ill., on Nov. 29, 1920.

Machine stalled on Dec. 3, 1920, due to the fact that it was not equipped with an equalizing valve. Machine was replaced by another machine which was equipped with an equalizing valve, although it was one of the first models of an equalizing valve used in these machines. This improved conditions, but did not entirely correct the trouble. The replacing machine was:

Type OC-2, Form E Refrigerating Machine #10030.

Installed Dec. 4, 1920.

Machine was transferred to Mr. Hughes' residence about March 16, 1921.

Machine failed on March 22, 1921, due to trouble with an old style equalizing valve. It was replaced by:

Type OC-2, Form E Refrigerating Machine #10029.

installed March 30, 1921.

Thermostat became grounded and was replaced by a new style thermostat on June 21, 1921. Service man necessary.

On April 13, 1922 service man was again called to Chicago to adjust control device.

Although this machine was functioning properly, it was replaced on Nov. 14, 1922 by a Form F machine with a vitreous

enameled brine tank, because it was our policy at that time to bring up-to-date all machines which were then in service.

Type OC-2, Form F Refrigerating Machine #10026.

Installed Nov. 14, 1922. In operation to date.

No adjustments.

M. GRISWALD, ERIE, PA.

Type OC-2, Form E Refrigerating Machine #10022.

Installed Sept. 9, 1920.

Machine was not operated during the winter and it was found on May 17, 1921 that it had failed because of the fact that the condenser coil had frozen and bursted.

Machine was returned to the factory, repaired and sent back to Erie.

In the meantime it was replaced by:

Type OC-2, Form E Refrigerating Machine #10030.

Installed May 26, 1921.

Much trouble was experienced due to the fact that proper voltage was not maintained on the line supplying this machine, the voltage often being 94 volts when machine was in operation. In many instances when the automatic control would attempt to start the machine, the voltage would drop to 74 volts, this being so low that machine would refuse to start. To overcome this, the machine was replaced by an outfit with a manually operated switch, so that it would be started when the voltage was normal. This manually operated machine was:

Type OC-2, Form E Refrigerating Machine #10022, which had been repaired and returned to Erie, where it was installed May 26, 1921.

So much trouble was encountered on account of improper line voltage, that the machine was removed on Aug. 10, 1921, and returned to the factory. Machine was still in operative condition. Installation was discontinued.

W.J. HARLEY - - KNIGHTSTOWN, IND.

Type OC-2, Form E Refrigerating Machine #10023 was installed on Sept. 1, 1920. Ran till Oct. 18, 1920.

Oct. 7, 1920, thermostat and water valve were not working properly. Wrote Mr. Hanley and asked him to make adjustments as per his suggestion in his letter of Oct. 6, 1920.

Before these adjustments were made, trouble was experienced because the machine would not start up with brine tank at cold temperatures.

On Oct. 18, 1920, the machine was removed and returned to the factory, inspected and it was found that this failure was due to the motor not being able to start the machine until the pressures were equalized. (This was one of the early models and was not equipped with an equalizing valve.) The machine was repaired and equipped with an equalizing valve which prevented a recurrence of this trouble.

In the meantime this machine was replaced at Mr. Hanley's residence by:

Type OC-2, Form E Refrigerating Machine #10026, installed Oct. 18, 1920. Ran until June 18, 1921. No adjustments during this time.

Machine failed on June 18, 1921, due to a grounded metal glass lead. This was one of the old style metal glass leads, and was ??? was of the later loads ??? with greater space between the conductor and the sheath at the end

inside the machine.

Machine was returned to the factory, repaired, and sent back to Knightstown, where it was again installed on July 1, 1921.

No adjustments until June 8, 1922, when the machine failed, due to gas leak through porous casting near the charging plug.

Machine was returned to the factory, and was replaced by:

Type OC-2, Form F Refrigerating Machine #10037 which was installed on June 14, 1922.

This machine operated in a satisfactory manner and without adjustment, but on Dec. 18, 1922, it was replaced by an up-to-date machine because it was our policy at that time to replace all machines which were equipped with the old style painted brine tanks. When the machine was returned to the factory it was in operative condition, but the brine tank was badly corroded.

It was replaced by:

Type OC-2, Form F Refrigerating Machine #10032, which was installed on Dec. 18, 1922, and which is still operating. No adjustments to date.

NEW YORK OFFICE OF GENERAL ELECTRIC COMPANY.

Type OC-2, Form K Refrigerating Machine #10024.

Installed Jan. 21, 1921.

The thermostat was adjusted on Feb. 10, 1921.

Machine failed on July 12, 1922, due to the fact that the fabroil gear had worn out.

This installation was discontinued. The only current available in the building was 220 volts, D.C. so that power had to be furnished the machine from a rotary converter which was operated only during office hours. This short period of operation of the machine did not allow it to maintain proper temperatures in the refrigerator.

APPENDIX #13-A

CORBLIN COMPRESSOR

Principle:

The membrane compressor is an apparatus in which a thin metallic disc pinched between two circular plates is allowed to oscillate up and down into elliptical spaces hollowed out in the thickness of the plates.

It is there oscillations of the disc which, by means of poppet valves placed in one of the plates, produces the suction and compression of the gas, which is sheltered by the membrane from the lubricant and other impurities.

A piston moving in a cylinder full of oil pushes the membrane up and down by oil pressure.

An extra small compensating pump replaces any oil which escapes between the piston and the cylinder, and thus, by maintaining a full supply of oil, insures that the membrane is always pushed down to its lower position, doing away with all clearance volume.

The membrane compressor does away with all oiling and stuffing boxes and preserves the gas in a pure condition, at the same time economizing the power. (See Communication (text illegible)

LeBlanc, January 3, 1921.) The fact that there is no internal oiling permits the use of gases which might attack the lubricant, and renders unnecessary oil separators which ordinarily

complicate other refrigerating machines. It also prevents any gumming of the valves and valve ports, which is one of the principal causes of failure of small machines. It also prevents the stirring of the lubricant and the refrigerant, which very often produces a soapsuds which interferes with the valves and sometimes make it necessary to dismantle the machine.

Elimination of the stuffing box eliminates the losses and permits the use of noxious gases. It is no longer necessary to watch the heating of the stuffing box, or to keep the piston lined up with the stuffing box. The absence of the stuffing box reduces the friction of the piston which moves in oil and gives a very high mechanical efficiency. Elimination of clearance volumes makes a very high volumetric efficiency.

The plunger of the oil pump has a relief valve in it so that when the pressure reaches a certain point the oil is allowed to go up through the plunger. This prevents breaking the machine by excessive oil pressures.

It is claimed that this membrane compressor has 50% better efficiency than some other types of small machines.

It can be taken apart completely by anyone in about two hours. The membrane (text illegible) three screws. The valves can be removed by loosening two other screws.

The crank shaft bearings and the connecting

red bearing are of the ball bearing type. The oil piston has piston rings.

These compressors for refrigerating machines would be put in any hands, taken apart completely, and put together again in a very short time. The working piston is the simplest kind of pump. Anyone can service these machines without any knowledge of machines.

There are two methods of taking care of machines. The first method prefers that the buyer should know nothing about the machine and should never take it apart. The second method, on the contrary, wants the buyer to understand the machine so that he can easily himself keep it in perfect repair throughout the long years. The well informed buyer is correct in preferring the last method.

Apparently this machine is only sold separate from refrigerator boxes. There are three sizes, as follows

	Refrigerating Capacity At 14°F	Motor HP	Water Gals per Hour	List Price
Refr. Machine A-1, complete with ice freezing compartment for 55 lbs. of ice	41 lbs.	$\frac{3}{4}$	53	9750 francs
Addition for brine pump mounted on freezing tank ready to run				450
Addition for idler pulley				200
Refr. Machine A-2, complete with ice freezing compartment for 110 lbs. of ice	82 lbs.	1.4	106	14750
Addition for brine pump				450
Addition for idler pulley				200
Refr. Machine A-3, complete with ice freezing compartment for 660 lbs. of ice	164 lbs.	2.5	212	26800
Addition for brine pump				450
Addition for idler pulley				250

The above are the list prices, and I do not know what the discounts are.

This company, Henri Corblin, Constructor of Complete Refrigerating Installations, claims to have been specialists in the refrigerating art for twenty-five years

ARStevenson,Jr-DW

February 29, 1924.

APPENDIX #14

SAVAGE ARMS COMPANY

- (1) Manufactured by: Savage Arms Company.
- (2) Address: Utica, New York.
- (3) Resources: This company has a manufacturing capacity of \$5,000,000, approximately, total for all plants. Their domestic refrigerating machines will not be available until August or September, 1923.
- (4) Patents: 1,373,174 Jay Grant DeRemer May 29, 1921
 1,373,175 " "
 15,590 " "
 15,591 " "
- (5) Remarks:
 The principle of the Savage Arms machine can best be described as follows.

a – Consider a tank full of mercury, with a screw dipping into it. The screw should be surrounded by a tube, so that the threads form a spiral passage.

[diagram]

The screw and the casing are rotated about their own axis. The threads pick up some mercury and trap some air ??? revolution. The mercury is too heavy to be carried around with the screw and, therefore, remains in the bottom. As the screw is rotated, the mercury is carried along the bottom, while the un trapped air is carried along the top.

If the upper and of the spiral passage is connected to an air receiver under pressure, the mercury is (Text Illegible) of these differences in height of mercury will be equal to the pressure against which the air is pumped.

Such a contrivance could be used as a pump to (Text Illegible) The refrigerant, but about 250 turns would be (Text Illegible)

in order to build up the required pressure. This would be quite bulky and require a great deal of mercury.

The Savage Arms Company have improved on this principle by using centrifugal force instead of gravity. In practice, the value of centrifugal force, which they use, is twenty-five times the force of gravity: therefore, only about ten turns are required.

The patents mentioned about have been granted to the Savage Arms Company covering this arrangement. These patents give a very complete description of the contrivance.

Briefly, it consists of a horizontal disc about 15" in diameter, which revolves about a vertical axis.

At the periphery of this disc, there is a bearing inclined about fifteen degrees from the vertical.

Mounted in this bearing is a tube about 4" in diameter by 15" high, shown in the drawing H-108901

The tube with the spiral passageway, although the bottom of it is carried in a circular path, does not rotate with respect to the earth. When the tube is on the right side, the centrifugal force is to the right, when the tube is on the left side, the centrifugal force is to the left. Thus, the centrifugal force revolves about the tube, pulling the mercury around with it.

In drawing H-108901, the auction chamber is represented by "A". The shaded portion shows the level of the mercury, which is held out by the centrifugal force. (The level of mercury is perpendicular to the centrifugal force.) When the table has rotated, bringing the machine to the left, the mercury will stand in the other side of this compartment. As the mercury swings around the compartment, it is caught by the spiral threads and, at the same time, a certain amount of air is trapped.

It will be noticed that the outside spiral slots

are shaded, showing that they are full of mercury; whereas, the inside spiral slots are filled with gas. As the centrifugal force changes from side to side (Text Illegible) the gas around through the spiral passage until both the mercury and the gas are delivered in the compression chamber, "B".

[diagram (Illegible)]

- 3 -

It will be noticed that in the compression chamber, "B", the mercury again stays in the outside with its surface perpendicular to the centrifugal force. The gas cannot get down through the surface of the mercury and, therefore, goes up the annular passage to the discharge tube, while the mercury flows up through the central passage, back into the suction chamber.

The suction and discharge tubes are wound up in spirals of the same shape as the hair-spring in a watch. About fifteen feet of pipe is used. As the machine rotates, these pipes are twisted about fifteen degrees. This is one degree per foot. The Savage Arms Company have checked up the strain in the material with the tests which have been made at the University of Illinois. This twist of one degree per foot, puts a strain on the material less than the yield point. Therefore, the material should last indefinitely. The Savage Arms Company have had some of these machines running about a year, without any sign of breakage.

This pump has the following advantages:

- a - No internal lubrication. Therefore, any refrigerant can be used, and an oil separator is not required.
- b - There is no stuffing box.
- c - It is impossible to explode the machine because after a certain pressure is reached the mercury will run backward through the spirals.

The machines which the Savage Arms Company have are still laboratory models, and look very expensive, but Mr. Goll, Mr. Dalton, Mr. Blake, and myself all feel that it should be possible to redesign this machine mechanically so that it could be built for a low factory cost.

So much money has been spent in trying to solve the domestic refrigeration problem along stereotyped lines, that it is reasonable to believe that real success can only be achieved by some unusual development. Mr. Perkins, the engineer of the Audiffren Company, told me that he did not (Text Illegible) be solved until somebody invented a machine which would be just as unusual today as the Audiffren was a dozen years ago. I believe the Savage Arms machine fills Mr. Perkins' specification.

The Savage Arms machine can also be built in larger sizes in a construction similar to the Audiffren construction. In this case, the spiral tubing is omitted and the compressor, condenser, and expansion coils are all included in one rigid body which is rotated about an axis.

[diagram (Illegible)]

The compressor and condenser end of this would be sprayed with water and the expansion end would be sprayed with brine. I believe that this Savage Arms machine is so much simpler that if properly pushed, it will supersede the Audiffren machine in the larger sizes.

TESTS OF THE SAVAGE ARMS MACHINE.

Schenectady, Feb. 28, 1924.

Mr. Robert Steck.
Fort Wayne Works.

Dear Mr. Steck:

I want to congratulate someone on the beautiful form in which Tests #1, 2, 3, 4, 5, 6, 7, 8 and 9, on the Savage Arms machine in the Bohn box were plotted up. It certainly looks as though the Savage Arms evaporator does not have sufficient area for heat transfer to maintain proper temperatures in the food compartment in 90 degree room, with the evaporator plates at 32 degrees, as contemplated. Apparently this machine will maintain an average temperature of about 50 degrees in the food compartment in a room temperature of about 85 degrees, but with room temperatures of 90 degrees the average box temperature rises to nearly 60 degrees. It would look to me as though they will have to either increase the area for heat transfer, or else use a box with better insulation.

Tests #10, 11 and 12, on the refrigerating unit by itself in our calibrated brine tank, to determine heat absorption, does not look consistent. Test 10 is the most satisfactory looking of the three and apparently indicates that with 27 degrees brine temperature and a room temperature of 76 degrees, the machine has an absorption of 476.81 B.t.u. per hour. This is very low. Apparently the power input under this condition is .66 watthours

per B.t.u. This is much worse than I expected.

Test #11 was apparently taken with approximately 28 degrees brine temperature and a room temperature of 85.5 degrees, and would indicate that, at this higher room temperature, the capacity had fallen off tremendously. I see a note on your test record at the end of this Test #11, stating that you purged out air. The presence of air in the system might account for the bad performance.

Test #12, taken with a brine temperature of about 34 degrees and a room temperature of about 80 degrees, looks bad too. As far as I can tell from the records which you sent me, you did not take the trouble to calculate Tests #11 and 12. I take this either as an indication that you felt there was something wrong with the machine during the test, or else that the machine was so poor that it could be plainly seen without calculation.

I am not sure how much brine you had in the tank during Tests #11 and 12, but on the assumption that you had 100 lbs. of brine, I have made the following calculations.

Test #11:

Average brine temperature – (Text Illegible)

Brine temperature rose from 26.8 to 29.2 degrees in

1³/₄ hours

Average power input – 304 watts

Average room temperature – 80.4 degrees

Average difference between room temperature and
brine temperature – 52.3 degrees

Average input to heating unit – 4.01
amperes at 10.4 volts

	<u>BTU per hr.</u>
Heating unit = $4.01 \times 10.4 \times 3.415 =$	142.5
Leakage with 52.3 degrees temperature difference, from curve =	100.
Warming up brine = $2.4 \times 100 \times .83/1.75 =$	<u>- 114.</u>
Refrigerating effect of machine =	128.5
Watt hours per B.t.u. = 2.37	

Test #12 Average brine temperature – 33.1 degrees
Brine temperature rose from 32.1 to 35 degrees in
2³/₄ hours

Average power input – 304 watts
Average room temperature – 80.1 degrees
Average difference between room temperature
and brine temperature – 47 degrees
Average input to heating unit – 4.28
amperes at 11.04 volts

	<u>BTU per hr.</u>
Heating unit = $4.28 \times 11.04 \times 3.415 =$	161.5
Leakage with 47 degrees temperature difference, from curve =	90.
Warming up brine =	<u>- 87.5</u>
Refrigerating effect of machine =	164.
Watt hours per B.t.u. = 1.88	

If our tests are correct, Mr. DeRemer certainly has a very wrong idea of the performance of his own machine. I think we were all impressed with the fact that Mr. DeRemer was a very good engineer and perfectly honest. It is very hard to

believe that his is fooling himself as much as our test would seem to indicate.

I have tried to check the performance of the refrigerating machine itself in our calibrated brine tank, which you made in Tests #10, 11 and 12, with the performance of the machine in its Bohn Syphon box in test #7. It is my understanding that the Savage Arms Company are using the Bohn Syphon box #43, which has the following outside dimensions:

30" wide

21" deep

47" high

This is equivalent to 48.6 sq. ft. of the insulated area.

This Bohn Syphon box #43 melted 24½ lbs. of ice per day with a room temperature of 72 degrees and an average food compartment temperature of 47 degrees. This is at the rate of .98 lbs. per twenty-four hours per degree difference.

Assuming that the insulation of the type #42 Bohn Syphon box is the same as the insulation of the type #43

Bohn Syphon box, the ice meltage per degree per twenty-four hours would be in proportion to the insulated area. Therefore, it might be reasonable to assume that the type #42 would melt $.98 \times 48.6/53.6 = .9$ lbs. of ice per degree per twenty-four hours.

In Test #7, the refrigerating machine started with a new charge of water at 32 degrees and froze this water up completely in 31 hours. It is my understanding that the pans of the Savage Arms machine hold 40 lbs. of water. To freeze this 40 lbs. of water and bring the temperature down to $24\frac{1}{2}$ degrees would require a refrigeration of 42 lbs. of ice. Since it is spread over 31 hours, this is a rate of refrigeration of 1.35 lbs. of ice per hour.

The average difference between the food compartment temperature and the room temperature during this time was $35\frac{1}{4}$ degrees. Therefore, the heat leakage to the box would be $35\frac{1}{4} \times .9/24 = 1.33$ lbs. of ice per hour. The refrigerating machine must therefore have been delivering 2.68 lbs. of ice per hour, which is equivalent to 386 B.t.u. per hour. The average input to the motor was about 317 watts, so that the power input was about .822 watt hours per B.t.u. This seems to ??? ??? ??? with ??? ???

In the ??? with Mr. DeRemer dictated on January 8th, while he was at Fort Wayne, he states that in a 62 degrees room temperature his machine has a capacity of 626 B.t.u.

per hour and should require 320 watts or less. At first glance, it might be said that this was consistent with our readings. We know that the capacity of our own machine falls off as the condenser temperature is raised. This test would seem to indicate that the Savage Arms refrigeration capacity also falls off as the condenser temperature is raised. On the other hand, our preliminary theoretical considerations led us to the belief that in the Savage Arms type of compressor there could be no re-expansion of clearance volumes. Of course, there is a falling off in the amount of refrigeration due to the fact that the larger the temperature difference between the condenser and the evaporator, the more of the liquid is evaporated going through the expansion valve.

The three tests to be compared are:

Observer	Brine Temperature	Room Temperature	BTU per Hour	Watt hours per BTU
DeRemer	30 degrees	62 degrees	626	.51
Fort Wayne, Test #10	27.5 degrees	76.2 degrees	477	.66
Estimated by Stevenson from Test #7	30 degrees	87 degrees	386	<u>.822</u>

The Fort Wayne Test #10 would indicate that there is approximately 4 degrees drop between the brine temperature and the evaporator temperature and that there is about 24.8 degrees rise between the room temperature and the condenser temperature. (I am very much surprised at this large difference between room and condenser temperature.)

In Mr. DeRemer's test, the liquid is condensed at 86.8 degrees and has a heat of liquid of 23.4 degrees B.t.u. per pound. In going through the expansion valve, the heat of liquid theoretically remains constant. Pure liquid at 26 degrees would have a heat of liquid of -2.5. Therefore, 25.9 B.t.u. must have been used up in evaporating some of the liquid while going through the expansion valve. The latent heat of vaporization of ethyl chloride at 26 degrees is 166.6 B.t.u. per pound. Subtracting 25.9, this leaves 140.7 B.t.u. per pound available for refrigeration. The volume of a pound at 26 degrees is 10 cu. ft., so that the refrigeration per cu. ft. is about 14.07 B.t.u.

In the Fort Wayne test, the liquid in the condenser is at 101 degrees, and has a heat of liquid of 29.5 B.t.u. The heat of pure liquid in the evaporator at 23.5 degrees would be -3.6. Therefore, 33.1 B.t.u. must be used up in evaporating some of the liquid going through the expansion valve. The latent heat of vaporization of ethyl chloride of 23.5 degrees is about 167.15 B.t.u. per pound. The net refrigeration per pound would, therefore, be 134.05 B.t.u. The volume of a pound at this temperature is 10.65 cu. ft., so that the refrigeration per cu. ft. would be 12.6 B.t.u.

In Test #7, which I calculated, the liquid in the condenser would be at (Text Illegible) and would have a heat of liquid of 34.1 B.t.u. The heat of pure liquid in the eva-

porator at 26 degrees would be -2.5 B.t.u. Therefore, 34.6 B.t.u. would be used up in evaporating some of the liquid as it goes through the expansion valve. The latent heat of vaporization at 26 degrees is about 166 B.t.u. The net refrigeration per pound is, therefore, 129.4 B.t.u. The volume is 10 cu. ft. per pound. Therefore, the refrigeration per cu. ft. would be 12.94 B.t.u.

These three calculations can be compared in a table, as follows.

Observer	Room Temperature	Difference in Pressure	Theoretical BTU per cu. ft.	Refrigerating Effect claimed BTU per Hour
DeRemer	62 degrees	21	14.07	626
Fort Wayne	76.2 degrees	27.7	12.6	477
Stevenson	87 degrees	42	12.94	386

Corresponding Displacement of pump Cu. ft. per hr.	Displacement of Pump Claimed by Savage Arms Co.	Apparent Volumetric efficiency	Watt hours per BTU
44.5	52	85.5	.51
37.9	52	73	.66
29.8	52	57.2	.822

One would think that the volumetric efficiency of a pump like the Savage Arms, where there is no re-expansion in clearance, would be 100% until the pressure rose to a point where the mercury pistons would actually be blown back against the centrifugal force. It is my understanding that the Savage Arms machine is designed for about 40 lbs. pressure difference and, therefore, in Test #7, with a theoretical pressure difference of 42 lbs., there might have been some blowing back. On

the other hand, the above apparent volumetric efficiency might be due to heat absorbed by the liquid in the float chamber and the pipes leading from the float chamber to the evaporator plates. Our tests seem to indicate that the temperature rise from the room temperature to the condenser temperature is 24.6 degrees, and that the temperature drop between the brine temperature and the evaporator temperature is 4 degrees. Then, as indicated above, the pressure difference with a brine temperature of 30 degrees and a room temperature of 87 degrees is 47 lbs. If our tests are correct, the Savage Arms Company have not allowed sufficiently for overload in designing their compressor for approximately 40 lbs. difference, because this pressure difference is sure to be exceeded on very hot days. It is hard to believe that the temperature rise from the room to the inside of the condenser could be as much as 24.8, when it is remembered that the Savage Arms Company have very good forced ventilation on the condenser.

Very truly yours,

ENGINEERING GENERAL

ARStevenson, Jr-DH

FCPratt

WSGoll

SHBlake

Appendix 15 ODIN

- (1) Name of manufacturer – Automatic Refrigerating Company.
- (2) Address – Hartford, Connecticut
- (3) Resources – This concern is well established as a manufacturers of commercial ice machines. Their manufacturing capacity is approximately \$2,000,000. and they have a paid in capital of \$750,000.

Mr. Owens, secretary and general manager of the Automatic Refrigerating Company, told me that the Consolidated Gas and Electric Company of Baltimore had offered to buy 10,000 machines if they could get them for \$200.00. The year, after which they will get on a manufacturing basis. They also expect to develop an intermediate size of about 10 cu. Ft. capacity.

I believe they have up to date made about 100 of the 5 cu. Ft. size, and about twelve of the 15 cu. Ft. size.

- (4) Cubic contents – 5 cu. Ft. and 15 cu. Ft.
- (5) Automatic or non-automatic –Automatic.
- (6) If thermostatic control, give range of temperature – from 42 to 46 degrees Fahrenheit.
- (7) Refrigerant used – Air.
- (8) Compressor – The pump apparently ran about 150 RPM. Each cylinder had two pistons, one of them made of bakelite. Apparently the compression takes place between the two pistons.
- (9) Air or water cooled – Air cooled.
- (10) Retail net price to user -

5 cu. Ft.	15 cu. Ft.
\$450.	\$750.

This price includes the refrigerator box.

If ice is wanted, \$50.00 extra is required to cover a brine arrangement.

- (11) Percent discounted to central stations – They handle this unit exclusively through their own direct branch offices.

APPENDIX #16.
WATER VAPOR MACHINE SUGGESTED BY
MR. A. R. DODGE

Mr. A. R. Dodge has suggested that we might use a set of discs as centrifugal vacuum pumps to reduce the pressure and cause the water to evaporate. He made one of those pumps consisting of two 8" discs, running at 12,000 RPM. The input to the motor was five amperes, 118 volts, or 590 watts. He got a total pressure difference of 26.35" of water, or 2.1 ft. of water, which equals .91 lbs. per square inch.

In order to make water vapor at 32 degrees, it is necessary to have an absolute pressure of .085 lbs. per square inch. The pressure difference between this and atmosphere would be about 14.61 lbs. If two of these discs will pump .91 lbs., then it might require about thirty-two discs in order to get the proper vacuum. (This is based on the assumption that the pressure difference is linear, whereas, it is very likely that at these lower pressures this law would not hold.)

(Text Illegible) B.t.u. refrigerating effect per hour, it would be necessary to pump about 3200 cu. Ft. of water vapor, which is about 150 times as large a volume as it

is necessary to pump with sulphur dioxide. Mr. Dodge had no tests to show what volume could be pumped with this rotary disc machine.

My feeling is that this scheme has the following disadvantages:

- a- Vibration and noise due to the high speed of the discs.
- b- Large volume of water vapor which would have to be pumped.
- c- Difficulty of obtaining a low enough vacuum.
- d- Although there are not sufficient tests are to be certain, the indications are that the power input would be more than 500 watts.

The method of cooling by evaporating water in a vacuum has been known since the beginning of the nineteenth century. Professor Leslie, in the year 1810, described a laboratory experiment in which water was frozen by placing it in a saucer under the receiver of an air pump. Professor Leslie obtained this high vacuum by placing under the same receiver another saucer containing sulphuric acid. After the air had been exhausted, the vapor of the water was given off freely and absorbed by the sulphuric acid.

Such a machine was made in 1878 by Windhausen, and was practically employed on a somewhat large scale by the Aylesbury Dairy Company in the making of ice. This machine was able to freeze about 12 tons of ice in twenty-four hours.

A compound air pump was used, maintaining an excellent vacuum of only one-twentieth of a pound per square inch. Six blocks of ice weighing 650 lbs. each are described as having been formed in about sixty minutes after starting.

Mr. Carre, in the year 1875, introduced for domestic purposes a small form of absorption machine using water and sulphuric acid, consisting of an air pump and a chamber to contain the acid.

This subject is discussed in detail on pages 47 through 51 of "The Mechanical Production of Cold", by Ewing, where it is estimated that the coefficient of performance of such machines was about one-sixth.

Corrected:
October 17, 1023.

APPENDIX #17.

SYSTEM OF REFRIGERATION
SUGGESTED BY R. W. DAVENPORT

The Detroit Edison Company are very much interested in the system of refrigeration suggested by Mr. R. W. Davenport, of 1583 Hurlbut Avenue, Detroit, Michigan. At the end of this appendix is a copy of a letter written on August 8, 1923, by one of the Detroit Edison sales engineers, Mr. A. D. McLay. In spite of Mr. McLay's enthusiasm, we would not recommend that the General Electric Company invest any money in this scheme, because we feel that any possible advantages would be overcome by additional complication and cost.

Mr. Davenport's system can best be explained by referring to the following diagrams.

(SEE DIAGRAM (Illegible))

I have made up the following hypothetical figures to illustrate the ideas which I gained from a conversation with Mr. Davenport.

“A” is the condenser and is held at a total absolute pressure of 29.7 lbs. per square inch. As explained later, the temperature of the mixture, while going through the condenser, drops from 170° Fahrenheit to 104° Fahrenheit.

It is then assumed that by means of some kind of carburetor, a mixture of one pound of air, .872 lbs. of vapor, and 7.3 lbs. of liquid tetrachloride are allowed to escape from the condenser into a nozzle “B”.

This nozzle is shaped so that the mixture will attain a velocity of about 720 feet per second, at which time the temperature will have dropped to 32° Fahrenheit, and the pressure will have dropped to 3.337 lbs. per square inch absolute. After attaining this velocity and low temperature, the mixture is led through a continuation of the nozzle, where it is allowed to absorb heat from the refrigerator. This would naturally cause the mixture to rise in temperature. This tendency to rise in temperature is partly counteracted by the fact that the velocity increases to about 834 feet per second so that the temperature does not rise higher than 50° Fahrenheit in the part of the nozzle which is absorbing heat from the refrigerator.

The third part of the nozzle is arranged to transform the velocity of the mixture into a static pressure.

the mixture slows down, the temperature rises to about 128.4° Fahrenheit, and the pressure rises to about 14.7 lbs. per square inch absolute. One of the advantages claimed for this machine is that, because the system is at atmospheric pressure at this point, it can be opened and fresh refrigerant poured in.

The pump takes the mixture at 14.7 lbs. per square inch absolute pressure and 128.4° Fahrenheit, and compresses it to 170° Fahrenheit and 29.7 lbs. per square inch absolute, in which condition it enters the condenser.

In preparing a temperature-entropy chart for a mixture of air, vapor, and liquid, there are several general rules which must be observed.

(1) The air and the vapor occupy the same space. Therefore, the product of the weight of air by its specific volume must equal the product of the weight of vapor by its specific volume.

$$\text{Lbs. of vapor per lb. of air} = \frac{\text{Specific volume of air}}{\text{Specific volume of vapor}} \quad (1)$$

In this investigation, we will neglect the volume of the liquid.

(2) Dalton's law states that the total pressure is the sum of the partial pressures.

$$\text{Total pressure} = \text{air pressure} + \text{vapor pressure} \quad (2)$$

(Text Illegible)

and total heat of carbon tetrachloride are all taken from Table VIII

on page 70, of "Properties of Steam and Other Vapors", by C. H. Peabody.

The point of zero entropy and zero heat has been taken as 32° Fahrenheit.

(4) The properties of air are calculated as follows:

$$\begin{aligned} \text{Specific volume} &= \frac{53.34 \times \text{absolute temperature (deg. F.)}}{144 \times \text{absolute pressure (lbs. per sq. in)}} \end{aligned} \quad (3)$$

$$\text{Total heat of air above 32° F.} = .242 (t-32°) \quad (4)$$

$$\begin{aligned} \text{Entropy of air} \\ \text{above 32° F. and} \\ \text{14.7 lbs. pressure} \end{aligned} = .557 \log_{10} (T/491.6) - .158 \log_{10} (P/14.7) \quad (5)$$

(5) The other rules can best be explained during the calculation of the cycle.

A hypothetical cycle for this mixture is shown on temperature-entropy diagram H-108913-A, which is attached. The detailed calculations are as follows. It will be found that the capital letters of the subscripts refer to the corresponding points on the temperature-entropy diagram.

A3. Suppose we have one pound of air and 8.172 lbs. of carbon tetrachloride at 104° Fahrenheit and a total pressure of 29.7 lbs. per square inch absolute.

$$\begin{aligned} \text{Total pressure} &= 29.7 \\ \text{Vapor pressure of ??} \\ \text{??} \\ \text{Air pressure} &= 25.55 \end{aligned}$$

$$\text{Absolute temperature} = 104^{\circ} + 459.6 = 563.6^{\circ}$$

$$\text{Specific volume of air} = \frac{53.34 \times 563.6}{25.55 \times 144} = 8.2 \text{ cu. Ft}$$

$$\text{Total heat of air} = .242(104 - 32) = 17.45 \text{ B.t.u.}$$

$$\text{Entropy of air} = .557 \log_{10}(563.6/491.6) - \log(25.55/14.7) = -.00985$$

From table, specific volume of C C14 = 9.38 cu. Ft.

$$\begin{aligned} \text{Lbs. of C C14 per} \\ \text{Lb. of air} &= \frac{8.2}{9.38} = .872 \text{ lbs.} \end{aligned}$$

Since there is a total of 8.172 lbs. of C C14 and .872 lbs. of this is vapor, there must remain 7.3 lbs. of liquid.

From the above information and a further use of Peabody's table, the following summary can be prepared.

	<u>Lbs.</u>	<u>Volume</u>	<u>Pressure</u>	<u>Entropy</u>	<u>Heat</u>
Air	1.0	8.2	25.55	- .0049	17.45
Vapor	.872	8.2	4.15	.163	91.
Liquid	7.3	---	----	.2003	105.5
Total	9.172	8.2	29.7	.3582	213.95

This point is plotted on the temperature-entropy diagram H-108913-A (Illegible) at 104° Fahrenheit and an entropy of .3584.

It is now assumed that this mixture goes through a perfect, frictionless, adiabatic expansion nozzle, where

it reaches a temperature of 32° Fahrenheit and a total pressure of 3.337 lbs.

$$\text{Total pressure} = 3.337$$

$$\text{Vapor pressure at } 32^\circ = \underline{.637}$$

$$\text{Air pressure} = 2.700$$

$$\text{Absolute temperature} = 32^\circ + 459.6 = 491.6^\circ$$

$$\text{Specific volume of air} = \frac{53.34 \times 491.6}{2.7 \times 144} = 67.5 \text{ cu. Ft.}$$

$$\text{Heat content of air} = .242 \times (t - 32^\circ) = 0$$

$$\text{Entropy of air} = .557 \log_{10} 491.6/491.6 = .158 \log_{10} 14.7-2.7 = .116$$

$$\text{Specific volume of C C14 per lb. of air} = 67.5/52.4 = 1.275 \text{ lbs.}$$

This leaves 6.897 lbs. of liquid.

	<u>Lbs.</u>	<u>Volume</u>	<u>Pressure</u>	<u>Entropy</u>	<u>Heat</u>
Air	1.	67.5	2.7	.116	0
Vapor	1.275	67.5	.637	.2424	119.34
Liquid	6.897	----	-----	0	0
Total	9.172	67.5	3.337	.3584	119.34

When the mixture entered the nozzle, it had a heat content of 213.95 B.t.u. It now has only 119.34 B.t.u. Since the nozzle was assumed to be frictionless and non-conducting, the difference 94.61 B.t.u. (Text Illegible)

$$94.61 \text{ B.t.u.} = 73.300 \text{ ft. lbs.} = \text{(Text Illegible)}$$

$$W = 9.172 \text{ lbs.}$$

$$2g = 64.4$$

$$V = 720 \text{ ft. per second.}$$

Of course, at this high velocity there would be a tremendous frictional loss, but this is neglected in this theoretical investigation of an ideal cycle.

It should be particularly noted that the properties were adjusted so that the entropy would remain constant.

The mixture now enters a part of the nozzle where it absorbs heat, thus performing its function as a refrigerating machine. This part of the nozzle is shaped so that during the evaporation the temperature will not rise above 50° Fahrenheit. In order to do this, it is necessary that the mixture should attain a higher velocity.

The point "B₂" represents the condition at the end of this period.

	B ₂					
	<u>Lbs.</u>	<u>Volume</u>	<u>Pressure</u>	<u>Entropy</u>	<u>Heat</u>	<u>Velocity</u>
Air	1.	154.3	1.22	.180	4.36	834
Vapor	4.81	154.3	1.078	.911	462.	834
Liquid	3.362	-----	-----	.024	12.05	834
Total	9.172	154.3	2.298	1.115	478.41	834 ft/sec

128.48 B.t.u. in Kinetic energy.

The detailed calculations are similar to these in the points previously calculated.

At the beginning of the refrigeration period “B₁”, the mixture had a total energy content of 119.34 B.t.u. in heat and 94.61 B.t.u. in Kinetic energy, making a total of 213.95 B.t.u. At the end of the refrigerating period, “B₂”, the mixture has an energy content of 478.41 B.t.u. in heat and 128.48 B.t.u. in Kinetic energy, making a total of 606.89 B.t.u. Therefore, the heat absorbed during the refrigerating process must have been 392.94 B.t.u.

The mixture now enters the third part of the nozzle between “B₂” and “B₃”, which is shaped so that the Kinetic energy will be transferred into static pressure. Neglecting friction, etc., it is theoretically possible to make this change at constant entropy. The point “B₃” represents the conditions after this change has been completed.

B ₃ .					
	<u>Lbs.</u>	<u>Volume</u>	<u>Pressure</u>	<u>Entropy</u>	<u>Heat</u>
Air	1.	28.2	7.7	.0880	22.34
Vapor	4.185	28.2	7.	.8940	514.
Liquid	3.357	----	----	.1340	70.5
Total	9.172	28.2	14.7	1.1160	606.89

It will be noted that the energy content, 605.89 B.t.u. remained constant and that the entropy, 1.116, also remained constant during this change, but that the pressure rose to 14.7 lbs. absolute and the temperature rose to 128.4° Fahrenheit. It is assumed that the mixture has lost its velocity as

that all the Kinetic energy must have been transferred into heat, giving a corresponding rise in pressure.

The change from “B₃” to “A₁” is made by the pump. The pump, therefore, takes a volume of 28.2 cu. Ft. at 128.4° Fahrenheit and 14.7 lbs. per square inch, absolute pressure. “A₁” represents the condition after adiabatic compression of the mixture by the pump.

A ₁ .					
	<u>Lbs.</u>	<u>Volume</u>	<u>Pressure</u>	<u>Entropy</u>	<u>Heat</u>
Air	1.	15.7	14.9	.062	33
Vapor	5.31	15.7	14.8	.932	597
Liquid	2.862	----	----	.122	80
Total	9.172	15.7	29.7	1.116	710

It will be seen that the entropy remains constant during this adiabatic compression, but that the total heat increases from 606.89 B.t.u. to 710 B.t.u. Therefore, the theoretical work done by the pump must be approximately 103.11 B.t.u.

A₂. In order to show that the cooling curve of this mixture of air, vapor, and liquid is not a straight line, I have calculated an intermediate point, “A₂”, at 140° Fahrenheit, which is shown on the diagram.

	<u>Lbs.</u>	<u>Volume</u>	<u>Pressure</u>	<u>Entropy</u>	<u>Heat</u>
Air	1.	10.5	21.05	.0234	26.15
Vapor	2.21	10.5	8.65	.4065	239.
Liquid	5.962	----	----	.2400	131.
Total	9.172	10.5	29.7	.6599	396.15

SUMMARY

Since 103.11 B.t.u. work was required to produce a refrigerating effect of 392.94 B.t.u., the coefficient of performance = $392.94/103.11 = 3.8$. The coefficient of performance of a Carnet cycle between 32° Fahrenheit and 104° Fahrenheit would be 6.48. It would appear, therefore, that this cycle is theoretically only about half as efficient as a Carnet cycle, in spite of the fact that we have neglected friction, etc. I feel quite sure that there would be very much frictional losses at these high velocities, which would still further lower the coefficient of performance.

Since the pump has to handle 28.2 cu. Ft. for each 392.94 B.t.u. refrigerating effect, it would be necessary to handle 72 cu. Ft. per thousand B.t.u. This does not seem excessive, but I feel quite sure that with the mixture traveling through the cooling coils at 720 to 834 feet per second, so much frictional heat would be developed that the net refrigerating effect would be very much reduced. This would make it necessary to pump a correspondingly larger volume.

Mr. Davenport makes the following claims:

- 1- A theoretical advantage in efficiency which is not borne out by the above calculations.
- 2- A small ratio of compression.
- 3- The ability ??? a refrigerant which is a liquid at atmospheric pressure and temperature, thereby making it possible to charge the machine with a flask.

- 4- The fact that any leakage of air into the machine is an advantage rather than a disadvantage.

On the other hand, Mr. Davenport has not yet perfected the machine mechanically and we foresee the following possible difficulties:

- 1- The volume to be pumped per thousand B.t.u. would be at least 72 cu. Ft., as compared with approximately 30 cu. Ft. for sulphur dioxide in our type OC-2 machine. Therefore, the pump would probably be more expensive.
- 2- We imagine that quite a complicated carburetor would be necessary in order that the mixture going to the nozzle would have the proper proportions of air, vapor, and liquid.
- 3- The design and construction of the expansion nozzle might be quite difficult.
- 4- Mr. Davenport has urged the advantage that the refrigerant can be resupplied easily from a flask. We feel that the type OC-2 machine, which is Hermetically sealed, will never require any resupply of gas.

Mr. Davenport suggests the following theoretical ideas for consideration:

- 1- A difference between a perfect gas and a mixture of saturated vapor and a gas.
- 2- Probable alteration of latent heat due to the attenuation of the liquid into films a few molecules thick,
(Text Illegible)
air and vapor.

- 3- He believes that the evaporation temperature at a certain pressure is lower when thoroughly aerated because, “The temperature of a body of liquid of a given tensile strength is limited only by the density of its own vapor in its surface contact layer.”

(SEE DIAGRAM (Illegible))

THE DETROIT EDISON COMPANY

General Offices
2000 Second Ave.
Detroit, Michigan

August 8, 1923.

Mr. A. R. Stevenson, Jr.,
Power & Mining Engineering Dept.,
General Electric Company,
Schenectady, N.Y.

Dear Mr. Stevenson: -

Now that you have, through the mediation of my company, been given full and complete information on the Davenport refrigerating process, you will, perhaps, judging from your conversation Saturday, act much as I would under similar conditions and proceed along the following lines:

1. I would immediately confirm, both by my own efforts and by consultations with my associates, the breadth and soundness of the principles of the process.

2. I would then, for an indefinite period, waste time, perchance endeavoring to think up some way to safely take advantage of the information given me with the object of evading the inventor's claims – or, in your words, “try to do the same thing another way.”

3. Eventually I might find myself wondering whether it would be cheaper to take a chance on making the things and fighting, or purchasing the invention.

But I didn't have a chance to talk with you alone at any time or I would have given you this further information which I am sure will direct your decisions. I have been present with Mr. Davenport at a number of recent conferences, some of them arranged by me because of my interest in domestic refrigeration for a number of years as a public utility problem, and the following groups are interested either as prospective manufacturers or users: (1) A man from New York directly representing Chase N. Schwab, (2) Mr. Carrier of the Air Conditioning Company, (3) National Ice Association (represented by the president and vice-president of the General Ice Delivery Company of Detroit), and (4) The General Electric Company, (Text Illegible) the Ice Association held the strongest hang, with Mr. Schwab coming along ascend. In a scrap either of these would be hard to

(2)

A. R. Stevenson, Jr.

August 8, 1923.

beat, but I am sure it will not come to that. It is not necessary to tell you why we would prefer not to have this in the hands of the Ice Companies.

I don't know whether you know, but I have been told several times, and again in this recent conference with the Ice crowd, that they have had for a number of years, like the German General Staff, a plan worked out which they would pursue if the right domestic machine came along and reached their control. That plan is to make the machine by the thousands and the various number companies, local ice concerns, would act as dealers. The machine would be put in your house on a rental basis of just enough to cover fixed costs and give a good healthy profit selling the machine eventually, also at a good profit, when the customer had learned by experience that the machine was right. They would, of course, include service and continue the rental policy where the customer didn't wish to buy. The user would, of course, pay for the current consumed.

Analyzing that you'll find it isn't such a bad plan. Manufacturers of some of our well known machines tell me they can manufacture their machine for \$70.00. Now if that is true, Davenport's can be made for \$30 to \$40, or less. Let us assume that this ice company purchasing machines by the thousand could place on in domestic ice boxes for \$100, where before these users had averaged \$5.00 a month for ice. The customer will at once have an increased electric bill ranging from \$15 to \$25 per year depending on the rate. In addition to this he will have to pay the ice company \$15 per year to cover fixed costs and something for service and profit. So it looks as though the ice company could continue to pay good dividends even if the user spent no more than originally spent for ice. But, of course, he would be willing to pay more.

Now my idea is that this is a public utility problem, that we are better fitted to give this kind of service than the ice companies, we already have the necessary service organization for such a simple machine, and that we should borrow their plan for distribution. But we cannot do this if this has companies control the situation. Hence, we want to see the thing manufactured by one of the big electric companies.

Now, if you decide that Davenport's machine is right in principle, and a couple of days should, with the eminent advisors available, enable you to do this, it follows that the domestic refrigerating problem is solved and the exploitation of

(3)

A. R. Stevenson, Jr.

August 8, 1923

this field is immediately available to you. If you do decide this, I believe it is for the best interests that you enter into at least tentative negotiations and thus get in line on it this week.

Your very truly,

THE DETROIT EDISON COMPANY

A. D. MoLay
Sales Engineer

Copies to
Miss S. M. Sheridan,
Vice President & Sales Manager,
The Detroit Edison Company.

Mr. T. D. Crocker, Chairman,
Associated Edison Committee on
Domestic Refrigeration.

P.S.

Mr. Davenport just phoned me that he will leave Monday for York, Pa., with Mr. Hayes of the General Ice Company. Couldn't you wire him to call at Schenectady on the way back?

GENERAL ELECTRIC COMPANY

Internal Correspondence

Mr. Davenport's Scheme for
Domestic Refrigeration.

DETROIT – August 22, 1923

Mr. A. R. Stevenson, Jr.,
Power & Mining Engr. Dept.,
SCHENECTADY.

I thank you for your August 20th
letter with the attached report concerning this
domestic refrigeration scheme.

We will get in touch with the
necessary people in the Detroit Edison Company and
convey to them the information that we are not interest-
ed in the purchase of this refrigeration scheme.

Yours very truly,
SM DEAN

ASSISTANT MANAGER.

SMD.VB.

APPENDIX NO. 18.

PARTIAL LIST OF PEOPLE CONSULTED BY INTERVIEW OR CORRESPONDENCE.

The following is a partial list of people who have been consulted either by interview or correspondence.

Mr. Henshaw's office was of special assistance in looking up the information concerning the competing machines and the capitalization of the competing companies.

Mr. Blake and Mr. Dalton furnished very valuable advice as to the proper method of conducting the investigation.

Mr. Goll, Mr. Wood, Mr. Evans, Mr. Crane, Mr. Orr and Mr. Givens of the Ft. Wayne Works, all furnished assistance in the preparation of the report.

Mr. Bows and Mr. Blakeman of the Commercial Service Section of the Publication Bureau prepared a report covering a publicity plan for domestic refrigeration, electric type, which furnished a general idea of the cost of advertising.

Advertising Department, (F.R.Davis.)

American Society Refrigerating Engineers.

American Washing Machine Manufacturers Association.

Mr. G. W. Alder, Engr. Of the Good Housekeeping
Institute.

Mr. Barber, Merchandising Dept. of the Western Electric Co.

Mr. A. K. Bayler.

Dr. E. J. Berg.

Mr. S. H. Blake

Mr. D. L. Boyd (Mr. Henshaw's Office).

Mr. W. J. Bray (Salesman handling Refrigeration Industry
in Chicago Office.)

Bureau of Standards

Mr. H. E. Bussey, Engineer Atlanta Office.

Mr. C. C. Chesney (who has a Coldak machine in his house)

Mr. F. P. Coffin (Research Laboratory)

Mr. R. N. Cole, Refrigerating Engineer.

Commercial Service Section of the Publication Bureau
(W. A. Bowe).

Mr. H. E. Crane, Mgr. Ice Machine Dept., Ft. Wayne Works.

Mr. T. D. Crocker, Minneapolis Light & Power Co.

Mr. G. W. Crossett (Salesman handling Refrigeration Industry
in the New York Office).

Mr. Neil Currie, Jr.

Mr. William Dalton.

Mr. A. P. Danz, Industrial Control Specialist.

Mr. C. Dansizen, Research Laboratory.

Mr. R. W. Davenport, Inventor.

Mr. M. C. Davison, Ingersoll-Rand Co.

Mr. J. G. DeRemer, Consulting Engineer, Savage Arms Co.

Department of Agriculture.

Mr. A. R. Dodge, Flow Motor Department.

Mr. Donahue, Former Service Man for the Isko Company,
Mr. Dwelly, Vice President of the Kelvinator Company.
Mr. Dwight, Society for Promotion of Electrical Development.
Mr. A. L. Ellis, Thompson Research Laboratory.
Dean Edward Ellery, Union College.
Engineering News Record.
Engineering Standards Committee.
Mr. H. F. T. Erben.
Mr. Sam Ferguson, Hartford Electric Light & Power Company.
Mr. G. T. Fielding, Director Commercial Research of
Bridgeport Works.
Fire Department, New York City.
Mr. Fischer, Vilter Company.
Mr. Fisher, Hurley Washing Machine Company.
Professor D. L. Fisk, University of Illinois.
Mr. A. J. Francis, Mgr. Practional Horse Power Dept.
Mr. Gardner, Statistician of the Western Electric Co.
Mr. Garrison (In charge of refrigeration for the
Ingersoll-Rand Co.)
Mr. W. S. Goll.
Mr. Grant, President of the Delco Light Co. manufactur-
ing Frigidaire.
Professor A. M. Greene, Princeton University.
Mr. V. R. Greene, Consulting Engineer.
Mr. A. C. Greenwood, Edison Illuminating Co., Boston.
Mr. Givens, Ft. Wayne Works.
Mr. A. W. Henshaw

Mr. J. R. Hewett.

Mr. N. H. Hiller, President of the Carbondale Company.

Mr. W. J. Hanley.

Hibbard Company, Agents in Cleveland for the Kelvinator
Corporation.

Mr. T. I. Jones, Brooklyn Edison Company.

Mr. D. F. Keith, President Keith Electric Refrigeration
Company.

Mr. F. M. Kimball.

Mr. Koken, Refrigerating Engineer.

Mr. Kossats, Service Mgr. Of the Frigidor Company.

Mr. N. J. Kingsbury.

Dr. Langmuir.

Mr. Lawrence, of the Firm of Thomas Murray, Consulting
Engineers.

Mr. Loffell, Pillsbury Becker Company.

Mr. N. McA, Lloyd, Consulting Engineer.

Mr. I. Lungard, of the Automatic Refrigeration Co.,
Inventor of the Odin.

Professor MacIntyre, University of Illinois.

Mr. D. J. M'Nulty, American Balsa Company.

Mr. J. F. McManus, Director of the Glacifer Company.

Mr. A. C. McLay, Sales Engineer, Detroit Edison.

Mr. L. S. McCormick, President of the MacLaren Frozen
Air Company.

Mr. P. L. Miles, Edison Electric Appliance Co.

Mr. G. E. Miller, Cleveland Edison Co.

Mr. Miller, Servel Company.

Mr. J. P. Morash, General Manager of the Lipman
Company

Dr. S. A. Moss, Thompson Research Laboratory

Mr. J. F. Myrick, Salesman for refrigerating apparatus
in the Baltimore Office.

Mr. C. R. Neeson, Consulting Engineer (formerly
engineer of the Knickerbocker Ice Co.)

Mr. C. K. Nichols, New York Edison Company.

Mr. J. E. North, Secretary of the Electric League of
Cleveland.

Mr. Oettli, Publication Bureau, General Electric Co.,
Paris, France.

Mr. Clark Orr, Engineer Ice Machine Dept., Ft. Wayne
Works.

Mr. Stuart Otto, President of the Hall Borchert Co.
which manufactures a domestic
refrigerating machine.

Mr. K. A. Pauly.

Mr. M. E. Pennington, Engineer investigating domestic
refrigeration for the National
Association of Ice Industries.

Mr. K. D. Perkins, Engineer of the Audiffren Company.

Mr. C. F. Pittman, Industrial Control Department.

Mr. Rae, Western Electric Company.

Mr. C. E. Reddie, Western Electric Company
(In charge of their investigation of
domestic Refrigerating apparatus)

Mr. Willard Reid, President of the Coldak Company.

Mr. E. L. Rich, Patent Department.

Mr. A. F. Riggs, Assistant Engr., Chicago Office.

Mr. H. J. Riffel (In charge of the service of the
type OC-2 machines on consignment
in Schenectady.)

Mr. J. F. Roche (In charge of advertising for the
Edison Electric Appliance Co.

Mr. Rogers, Sauter Company.

Mr. Paul Schlingman, Salesman in charge of Refrigeration
Industry in the St. Louis Office.

Mr. E. B. Seitz, Secretary American Association of
Washing Machine Manufacturers.

Mr. J. A. Smith.

Mr. E. B. Smith, Industrial Control Specialist,
Cincinnati Office.

Mr. Sorren, Hartford Electric Light Company.

Dr. Steinmetz.

Mr. T. K. Stevenson, Western Electric Company.

Mr. C. W. Stone.
Superintendents of Water Works in eighty-one cities.

Professor Elihu Thompson.

Mr. C. K. Trip of the Lynn Works.
Washington State College.

Mr. E. G. Waters.

Mr. D. W. Weed (Who make a report previously on this
same subject).

Mr. E. T. Williams, President of the Williams Simplex
Refrigerating Company.

Mr. Wilson, Salesman for the Frigidair in the
Albany District.

Mr. J. J. Wood, Ft. Wayne Works.

Mr. Zimmerman (Formerly Service Man for the Carbonic
Machine Company).

APPENDIX NO. 19

LIST OF MANUFACTURERS DESIRED EITHER BY MR. STEVENSON
OR MR. CRANE.

The following is a partial list of manufacturers of domestic refrigerating machines which have been personally investigated by either Mr. Crane or Mr. Stevenson. A great many of the other machines listed in the appendixes have been investigated by representative of Mr. Henshaw or members of General Electric Company Local Offices.

M. B. Arnold.

The American Balsa Company.

The Audiffren Company.

The Autofrigo Company

(Sample machine tested by Mr. H. E. Crane)

The Coldak Company.

Common Sense Ice Machine Company.

The Copeland Company.

The Federated Engineers Development Corporation.

The Freezerator Company.

The Frigidaire Company.

The Frigidor Company.

The Glacifer Company.

The Havenstrite Company.

George Horawa Company.

The Isko Company.

The Kelvinator Company.
Professor Keyes Machine.
The Lipman Company.
Mac Laren Frozen Air Corporation.
The Horwalk Company.
The Odin Company.
Savage Arms Company.
The Serval Company.
Universal Company.
Utility Ice Machine Company.
Williams Simplex Refrigerator Company.

Appendix 20 M.V. ARNOLD's MACHINE

- (1) Some of manufacturer – Mr. M. V. Arnold.
- (2) Address – Furniture Building, Evansville, Indiana.
- (3) Resources - ?
- (4) Model – There is only one model.
- (5) Size motor – 1/8 H.P. with water condenser at 40 lbs.:
or, on ¼ H.P., with air condenser at 80 lbs.
- (6) Cubic contents – 15 cu. Ft.
- (7) Automatic or non-automatic – Automatic.
- (8) Place where machine is mounted – it can be located in or
away from the ice box any reasonable distance without pipe
insulation.
- (9) Model temperature of ice box – 40 degrees Fahrenheit.
- (10) Refrigerant used - ?
- (11) Is there a stuffing box – No.
- (12) Air cooled or water cooled – Water.
- (13) Compressor – One cylinder.
- (14) Brine tank used or direct expansion – Brine tank.
- (15) Detail net price to user- ?

Mr. Arnold says that the machine could be
manufactured for \$75.00 on a production of ten a day.

- (16) Average hours operated per day – 9 hours.
- (17) Guarantee – Unknown.
- (18) Service – No arrangements have been made for servicing
this machine, as Mr. Arnold has made only the one machine.

Remarks:

(Text illegible)

Mr. H. E. Crane, of the Fort Wayne Office:

#2 – M. V. Arnold

“The design of the machine is rather crude. The only thing new and novel is the use of sylphon bellows instead of a stuffing box.

“The outfit consists of a gear chamber, a walking beam chamber, and a compression and condensing chamber. The motor shaft extends into the gear chamber, and on the end of the shaft is a pinion which meshes with the bronze gear. There is a crank pin in this gear on which is a rectangular guide block. This guide block travels in a slot in our end of the walking beam. The walking beam is carried on trunnions supported by the beam chamber, which chamber connects the gear chamber with the compression chamber. The beam chamber is horizontally sealed from the gear chamber by a sylphon. One end of the sylphon is clamped to the gear chamber, and the other end sealed around the walking beam which passes through the center of the sylphon. On the other end of the walking beam is a connecting rod, which connects with a single acting cylinder. The piston over-runs the intake port, and the exhaust is through a poppet valve in the head of the cylinder. The cylinder exhausts into the condensing chamber. Water is admitted to a coil at the lower part of the condensing chamber and comes out at the top. The machine was originally designed for a float valve, but he had trouble with the float, and has changed over to a diaphragm type of expansion valve. He uses two sylphons with a combination of levers for control of his motor and water supply. One sylphon is connected with the compression chamber, and this controls the water valve. The other sylphon is connected with the suction line of the compressor and controls the motor.

“The evaporator consists of a copper coil immersed in a tank of brine.”

APPENDIX NO. 21.

JOHNS-MANVILLE COMPANY.

This company sells the Audiffren machine and Appendix No. 22, Audiffren, should be referred to. These machines are really too large to be called domestic machines in the strict sense of the word. The sizes are as follows:

Size	No. 2.	No. 3	No. 4	No. 6.
Cooling effect (ice melted) per hour	16 lbs.	40 lbs.	80 lbs.	160 lbs.
Ice making capac- ity per hour.	11 lbs.	27 lbs.	55 lbs.	110 lbs.
*Condensing water per hour @ 70°F.	40 gal.	95 gal.	190 gal.	380 gal.
Power required at full load B.H.P.	.4 to .6	1 to 1 ¼	1 ¾ to 2 1/6	3 ½ to 4 ½
Speed of machine (R.P.M.)	380	280	190	140
Price	\$ 1600.	\$ 2500.	\$ 3500	\$ 5500.

*The quantity of condensing water required depends upon the temperature of the available supply.

**These prices include the machine, motor, brine circulating pump, brine lines, cooling coils for the refrigerator, delivered and erected in running order within a radius of fifty miles of New York City. The price of the refrigerator is not included.

Where electric current for power is obtained at 6 cents

per K.W. hour, and condensing water at \$1.00 per 1,000 cubic feet, these machines will furnish refrigeration at from 16 cents to 22 cents per hundred pounds of refrigerating effect.

The Johns-Manville Company make the statement that the Refrigerator Box can be held 10 to 15 degrees colder than when ice is used.

In case the reader is not familiar with the Audiffren machine, the following brief description may be of interest.

The machine looks like a large dumbbell. One end of the dumbbell contains a two cylinder double acting compressor which hangs on a lead weighted pendulum. The gas is compressed by this compressor and the heat of condensation is taken away by cooling water in which that end of the dumbbell revolves. The liquid sulphur dioxide goes through an expansion valve and through the hollow shaft to the other end of the dumbbell where it evaporates. This evaporation absorbs heat from the brine in which the expansion dumbbell is immersed.

These dumbbells are completely sealed up and the chance of leakage of the refrigerant is thereby very much reduced. Some of these dumbbells have been in operation for eleven years without being opened.

The dumbbells are mounted in bearings and are revolved by a belt from a motor. As the dumbbells revolve the compressor with the pendulum hangs stationary and is

operated by the revolution of the dumbbell.

Appendix No. 1 shows that only 5% or 6% of these dumbbells are ever returned for repairs. The chief difficulty has been due to the fact that in case the cooling water supply is shut off, the pressures build up and the compressor with its pendulum instead of hanging stationary, turns over with the dumbbell. This causes an unbalance which bends the shaft. Incidentally, this is a safety feature because it prevents the machine from blowing up.

The machine includes a centrifugal unloading device which equalizes the pressures in the compressor cylinders and allows the motor to start up easily.

There is also quite a complicated oiling system which insures a circulation of oil through the machine.

The dumbbells are made of special navy bronze and are carefully tinned. This tinning operation fills in the pores in the casting which might cause a leak. There is only about one machine a year returned on account of leaks.

In all the years the General Electric Company have been manufacturing these machines, there have only been one or two valve springs broken.

The expansion valve is of the float type.

There is a special (illegible text) the gas in the expansion bell and scoops up the oil so that

it will be returned with the gas to the suction side of the compressor. The expanded gas is sucked back through the large tube in the hollow shaft, whereas the liquid goes from the compressor bell to the expansion bell through a small tube down the center of the shaft.

APPENDIX NO. 22.

AUDIFFREN.

1. Name of Manufacturer – Audiffren Refrigerating & Machine Company.
2. Address – 90 West Street, New York City.
3. Resources – This concern has an authorized capital of One Million Six Hundred Thousand Dollars, (\$1,600,000.) and Two Hundred Thousand Dollars, (\$200,000) of this was issued at par in 1911.
4. This company was organized by Mr. Griscom about 1911 and purchased the American rights to the Audiffren patents from the Singrun Company. They arranged with the General Electric Company to manufacture these machines and with the Johns-Manville Company to sell them. The contract between the Audiffren Company and the General Electric Company contained the following paragraph:

“First, the factory cost is to be computed on the basis in use from time to time by the General Electric Company at its factory where said machines are manufactured (the additions to direct labor to cover overhead charges no to exceed 100% on direct labor and not to exceed 5% on material) but not including any development. To the figure thus obtained is to be added twenty five percent (25%), and to the total thus arrived at is to be added ten percent (10%) and to this is to be added development at cost as ascertained by the

methods in use from time to time at the said factory.

“Nothing herein contained shall operate as an admission by the General Electric Company of the ownership, scope or validity of any patent or patent rights owned or claimed by the Refrigerating Company, nor shall anything herein contained be construed as restricting the right of the General Company to make, use and sell to others to be sold and used, refrigerating machines of any design or construction whatsoever except the Audiffren machines of this contract, provided however that should the General Company manufacture and sell refrigerating machines competing with the Audiffren machine in the same capacities, then and in that case the Refrigerating Company shall have the right to terminate this agreement by sixty days notice in writing served on the General Company to that effect.”

Appendix No. 1 shows that the overhead on the present manufacture of the Audiffren machine at our Ft. Wayne factory greatly exceeds 100%. This business is, therefore, no longer attractive to the General Electric Company unless the volume can be increased and the contract changed.

It is interesting to note that the smallest size Audiffren machine is rate at 100 lbs. of ice in twenty-four hours, whereas the Ft. Wayne type O.C.-2 domestic refrigerating machine has a capacity of considerably less than 200 lbs. of ice in twenty-four hours. Originally all these Audiffren

machines were water cooled and were sold through the Johns-Manville Company. For a description of them see Appendix No. 21, Johns-Manville.

5. Comparatively few of the Audiffren machines have been sold for use on domestic refrigerating installation because of the large floor space required, the excessive weight and the open condenser which combine to make a serious installation problem.

6. Two of the important patents on the Audiffren machine are No. 1,155,780 which does not expire until October 5, 1932, and No. 1,424,826 which covers the automatic control and was issued Aug. 8, 1922.

7. Recently the Audiffren Company has developed an air cooled machine. Our Ft. Wayne factory furnished them a No. 2 size of two cylinders, thus reducing the capacity. The Audiffren Company have soldered on copper fins to the dumbbells in order to avoid water cooling and a brine tank. A rotary motion of the dumbbells furnishes a fan action so that the heat transfer is very good. When the room temperature is 110 degrees Fahrenheit, the condenser pressure was only 89 lbs.

The dumbbell will be installed (illegible text)
the fans on the expansion end will suck the warm air in at the bottom.

The input to the motor is 300 watts and it runs about

half the time when refrigerating a refrigerator having 12 cu. Ft. food storage capacity.

8. Mr. Perkins, the engineer of the Audiffren Company, gave me the following list of costs:

Dumbbell	--	\$ 200.00
12 cu. Ft. Refrigerator	--	200.00
1/5 HP motor	--	26.00
Bearings	--	15.00
Base	--	25.00
Idler	--	10.00
Copper in fins	--	18.00
Soldering copper fins		10.00
Thermostat and Starter		30.00
Assembly	--	<u>41.00</u>
Total Cost	--	\$ 575.00
Probable selling price, approx.		\$ 900.00

Note: For description of the water cooled machines, attention is again called to the Appendix No. 21, Johns-Manville.

AUTOFRIGOR

- (1) Name of manufacturer – Escher Wyss & Co.
- (2) Address – Zurich, Switzerland.
- (3) Resources - ?
- (4) Models – A-301 A-501
- (5) Size motor - 1/4 H.P. 0.35 H.P.
- (6) Cubic contents - 14 cu. Ft. 25 cu. Ft
- (7) Dimensions: See catalogue Data Folder #704
- Weight - 360 lbs. 480 lbs.
- (without refr.) (without refr.)
- (8) Ice Making – 5 to 10 lbs. ice 8 – 16 lbs. ice
- daily daily
- (9) Place where machine is mounted – in top of refrigerator.
- (10) Automatic or non-automatic – Literature describes no automatic control.
- (11) Usual temperature of ice box - 35° to 40°
- (12) Refrigerant used – Methyl chloride.
- (13) Is there a stuffing box – No No
- (14) How often resupplied - Never Never
- (15) Is gas considered dangerous or not – Not (See appendix on refrigerants.)
- (16) Safety shut-off – None mentioned.
- (17) Air or water cooled - Water Water
- (18) Water per day - 13 gals. Per hour 13 gals per hour
- (19) Compressor – One double acting, oscillating cylinder, 1400 RPM.

#2 - Autofrigor

- (20) Brine tank used for direct expansion – Brine for ice, but Apparently direct expansion for cooling.
- (21) Detail net price to user – Unknown.
- (22) Percent discounts to deplere – Unknown.
- (23) Average hours operated per day – 6 to 10.
- (24) Estimated KW-hours per day – 1.5 to 2.5.
- (25) Guarantee – Unknown.
- (26) Second hand business – Unknown.
- (27) Service – The Escher Wyss & Co., will manufacture this machine in Switzerland for exploitation to the United States because the offers they received from America did not come up to their expectations. They will organize a special sales organization for these machines in the United States, and after they have been successfully introduced on the American market they will make arrangements for their manufacture over here.

Remarks:

This machine is almost identical with our Fort Wayne OC-2 machine. The chief differences are as follows:

a- The stator of the motor is outside the machine and the power is transmitted magnetically through a thin metal diaphragm of non-magnetic material of high electrical resistances situated in the air gap of the motor, forming a seal around the rotor. Our Fort Wayne engineers tested one of these machines and prepared technical report #15201, and they point out that this metal diaphragm in the air gap heats up very badly. Of course, the Swiss engineers may have recently discovered a more high resistance material in which the eddy current losses would be less.

b- The brine tank of this machine is corrugated. This is theoretically and advantage because it gives a larger area for absorbing heat. There is danger that this construction would be more expensive than our present smooth tanks.

Mr. Bosworth said that the Escher Wyss Company sent seven Autofrigor machines to this country.

#3 – Autofrigor

The principal advantage of the Autofrigor is that it has no packing whatsoever, as the whole pump and all moving parts are enclosed in the ice machine itself. For this purpose the rotor is surrounded by a very thin sheet of special metal. A special lubrication system for the motor as well as for the compressor pump is applied. Another essential part of the Autofrigor is the device to prevent the nozzles from freezing: there is also a special device to indicate if the rotor is revolving or not.

Appendix 24

BAUER & WAHL

- (1) Name of Manufacturer – Bauer & Wahl, Engineers and Contractors.
- (2) Address – Place Kleber, Strasbourg.
- (3) Resources - ?
- (4) Models – Three (4000, 8000, and 12,000 frigorics per hour)

Remarks:

The advertisement says that this machine is of the Linde system. The picture looks like a small size ammonia installation. It looks more like a butcher shop rather than a domestic machine.

Appendix 25

BRUNSWICK

Mr. Danz, the industrial control specialist of the New York Office, said that Major Holmes of the firm of Miller, (illegible text), Hutchinson, had invented a domestic refrigerating machine in which there is no stuffing box because the piston is pushed through a slyphon bellows. Mr. Danz understood that the Brunswick Company had taken this up.

Ed note: this may have been manufactured under the tradenames Holmes and Allison

Appendix 26

CHILRITE

- (1) Name of manufacturer – Winter Machine Company
- (2) Address – Pawtucket, Rhode Island.
- (3) Resources – This concern has an authorized capitol of \$200,000.00.

COLDAK

- (1) Name of Manufacturer – The Coldak Company.
- (2) Address – 40 Napier Street, Springfield, Mass.
- (3) Resources – Paid in capital, \$36,000.00; manufacturing capacity, \$150,000.00; output in 1922, \$100,000.00

This Company have sold three hundred machines and are building four hundred more now.

They have several orders for about fifty machines for apartment houses. They have just received one large order for 398 machines to one company, 374 for one apartment house, and 24 for another. They are making about six machines a day.

The machine was put out commercially in June, 1922, and some of them have ran ever since without and attention. Mr. C. O. Chesney, manager of the Pittsfield Works, is very much pleased with one that he put in last October.

The following is quoted from a letter from Mr. Wm. Reid, president of the Coldak Company:

“We regret very much that we are not in a position to make any further sales connections at this time, as we have been very much over-sold for the past eight months in spite of substantially increased production facilities.

“We are now laying plans for still greater production and expect to be in a position within the next four months to extend our dealer connections.”

- (4) Development -
- (5) Models – “A” “B” “C”
- (6) Size motor - ½ ¼ ?
- (7) Cubic Contents- 20 – 40 cu. Ft. Not over ?
- 20 cu. Ft.
- (8) Ice making at twelve and a half pounds of ice in just barely sufficient to freeze two quarts of ice cream. This can be obtained in five or six of the trays.

#2 – Coldak

They make about twenty pounds of ice per KW-hour: if the machine were water cooled, they might make six pounds of ice more.

- (9) Automatic or non-automatic – Automatic.
- (10) Place where machine is mounted – in basement.
- (11) If thermostatic control, give range of temperature - 38° to 50°.
- (12) Usual temperature of ice box – They are willing to put their machines in any ice box, but guarantee brine temperature and not degrees temperature. They try to keep the brine between 20 and 22 degrees Fahrenheit.
- (13) Refrigerant used – Ethyl chloride.

Ethyl chloride has more B.t.u. per pound than anything except ammonia. It burns quite fiercely at any opening. It is very unlikely that enough would get into a room to cause an explosion. They furnish two pressure gauges on a machine at a total cost of about \$1.50. All the valves are arranged so that a special wrench would be required so that a customer could not fool with it.

When ethyl chloride burns, it gives off chlorine.

- (14) Is there a stuffing box – Yes.
The stuffing box is arranged with a spring which gradually takes up the wear. This has to be tightened about once a year.

The stuffing box on the Coldak machine is similar to the gland stuffing box on the Isko machine, which has worked well for years.

- (15) How often resupplied – The Coldak company have not yet had long enough experience to know how often ethyl chloride must be renewed.
- (16) Cost of new refrigerant - ?
- (17) Is gas considered dangerous or not – See appendix on refrigerants.

#3 - Coldak

- (18) Lubricant – They put a special oiling system on the motor with a tank large enough so that the oil only has to be renewed once every two years.

Sometimes, if the machine is shut down for long, the oil becomes thin by being diluted with liquid ethyl chloride, alcohol and water. This thin oil does not make a good seal in the pump and sometimes the pump will not pump itself out. It is then necessary to shut off the supply of liquid to the expansion valve for about one-half hour. The machine will then pump a vacuum and get very hot. This vaporizes the ethyl chloride, leaving the oil somewhat thicker. Then, the supply of liquid to the expansion valve can be opened and machine will operate successfully.

- (19) Air or water cooled – Air.

- (20) Compressor – Rotary.

This machine has a two stage herringbone gear rotary pump. In the past, the Isko Company and others have had rotary pumps, but they have been single stage and have operated with a differential of as high as 100 lbs. The pressures encountered with ethyl chloride run anywhere from 25 to 40 lbs. This is divided into two stages so that probably the explanation of their success.

The gear wheels in the pump are especially designed. Apparently there is about 2/1000 clearance. They have a spring coupling which allows the motor sufficient and play and also makes it easier for the motor to start the pump.

On a damp hot day, the conduction and convection from the box is greater, making more work for the ice machine. Their pump has so little clearance that it pumps the same amount of refrigerant in the hot weather as in cold weather. This was demonstrated by tests which they showed me. They have a hot room for testing their machines, which is heated electrically.

- (21) Brine tank used or direct expansion – brine tank.

- (22) Retail net price to user - “A” “B” “C”
 \$325.00 \$295.00 ???

- (23) Percent discounts to dealers – At present, they give dealers 35 percent, the salesman getting 15 percent of this.

#4 – Coldak

- (24) Does price include:
- | | | | | |
|--------------|---|-----|-----|-----|
| Refrigerator | - | No | No | No |
| Brine tank | - | Yes | Yes | Yes |
| Installation | - | No | No | No |

The dealer makes a separate charge for delivery and installation.

- (25) Average hours operated per day – 6 hours.
Mr. C. O. Chesney, manager of the Pittsfield Works, says that the machine runs for about one hour and shuts down for three.
- (26) Guarantee –

“The COLDAK Company in lieu of all implied warranties hereby expressly agrees to correct any defects of labor or material in COLDAK machines which develop under normal and proper use within one year from the date of shipment thereof, provided the Purchaser gives the COLDAK company immediate written notice of such defects.”

- (27) Service – The Coldak Company showed me one machine which has been running for 4 ½ years and is still running very quietly.

They have no trouble with leakage from their stuffing box. They lead high pressure oil into the stuffing box and some oil comes out, but apparently no ethyl chloride gets out.

The originally had trouble with selective freezing and blocking the expansion valve. They have applied for a patent on adding three or four ounces of alcohol, which prevents the moisture from freezing very successfully.

Once in a while, their machine has to be shut down over night in order to defrost. The melting of the frost carries away odors which have collected around the brine tank. A drain is necessary in order to carry away the melted frost.

The Coldak Company say that Coldak machines are entirely dependable and automatic and do not require any attention from the owner: they start and stop themselves, even the electric motor automatically oils itself and carries a two years' supply of oil in the sight feed bottle.

Appendix 28

COLDMAKER

- (1) Name of manufacturer – Toledo Coldmaker Company
- (2) Address – Toledo, Ohio.
- (3) Resources = The paid in capital of this Company is \$45,000.00. and they have a manufacturing capacity of approximately \$100,000.00, and distribute through jobbers.
- (4) Size motor – Unknown.
- (5) Cubic contents – Is for installation in any box.
- (6) Ice making – There is a compartment where ice can be made or desserts frozen.
- (7) Automatic or non-automatic – Automatic.
Air or water cooled – water.
- (8) Place where machine is mounted – The cooling coils and ice trays are installed in the ice chamber of the refrigerator. The machinery is installed in the basement or other out-of-the-way place.
- (9) If thermostatic control, give range of temperature – A variation of two degrees from the desired temperature in the food compartment actuates the thermostat which starts or stops the compressor instantly.
- (10) Refrigerant used – Ammonia.
- (11) How often resupplied – About seventy-five cents worth of ammonia (one quart) will serve indefinitely.
- (12) Is gas considered dangerous or not – Yes (See appendix on refrigerants.)
- (13) Air cooled or water cooled –
- (14) Brine tank used or direct expansion – Brine tank.
- (15) Compressor – two cylinder, with pistons only 1 ¼ inches in diameter.
- (16) Retail net price to user – Unknown.
- (17) Percent discounts to central stations – Unknown.

#2 - Coldmaker

- (18) Guarantee – Unknown.
- (19) Service – this machine has been built and sold for over eight years. The following Coldmaker Company has been making and selling refrigerating machines for meat markets, dairies, etc., for many years.

Appendix 29

COMMON SENSE

- (1) Name of manufacturer – The Common Sense Ice Machine Company.
- (2) Address – Chicago, Illinois.
- (3) Resources – This company has a paid in capital of \$30,000.00.

Mr. A. G. Darling, of this department, says that this Company has so many orders that it absolutely refuses to sell any of these machines for installation outside of Chicago. He has written them for bulletins, but they do not even answer his letters.

- (4) Model – Style “A”.
The Common Sense Ice Machine Company will sell their machine for use with any ice box.
- (5) Size motor – No motor is used.
- (6) Trays – 4.
- (7) No/ cubes per tray –
- (8) Automatic or non-automatic – Automatic.
- (9) Place where machine is mounted – At any distance from the refrigerator up to 40 feet.
- (10) If thermostatic control, give range of temperature - 28° to 38° Fahrenheit.
- (11) Usual temperature of ice box – 30 degrees Fahrenheit.
- (12) Refrigerant used – Aqua-ammonia (water & ammonia).
- (13) Is there a stuffing box – none except in the valve stem.
- (14) How often resupplied – Unknown.
- (15) Is gas considered dangerous or not – Yes (See appendix on refrigerants).
- (16) Air or water cooled – water.
- (17) (illegible text)

#2 – Common Sense

- (18) Compressor – No compressor is used. It is an absorption machine.
- (19) Brine tank used or direct expansion – Brine tank.
- (20) Retail net price to user - \$450.00.
This price includes the installation with water and gas.
- (21) Percent discounts to central stations – Unknown.
- (22) Does price include:
 - Refrigerator - No
 - Brine tank - Yes
 - Installation - Yes
- (23) Average hours operated per day – The machine starts and stops once a day, running for a period of about two hours.
- (24) Cu. Ft. of gas used per day – 150 cu/ft.
- (25) Guarantee – Unknown.
- (26) Service – The salesman at the People’s Gas Company in Chicago claims that they have sold about fifty of these machines. Some of them have been in service for two years, and he claims that they have no trouble or service calls.

It seems likely that some of the five control diaphragms might crystallize sooner or later.

Mr. Roberson, of the Chicago Office, says that this ice machine is different from any other that he has seen, in that it has no rotating parts, and the machine appears to be very simple to maintain.

He also says that as far as he was able to learn, there have been no explosions, and the attendant was very eager to explain that it was impossible for this machine to explode, explaining that the blow-off valve (illegible text)

Mr. A. G. Darling says that in May, 1922, the peoples’ Gas Company had thirty or forty machines out and had had no complaints or repairs. In one instance, they sent out a man to adjust the thermostat to hold a different temperature from that for which it was originally set.

#3 – Common Sense

Remarks:

There is a pilot light on this machine. The difference in pressure between the generator and the condenser turns the water from the condenser to the generator and this change in the water operates the pressure valve, which cuts off the gas. There is a non-return valve between the generator and the condenser. The brine temperature is controlled by the expansion valve. There is a blow-off valve into the water discharge pipe.

There are two diaphragms which operate the water valves. One of these is connected to the generator and the other one to the condenser. There is a diaphragm operated by water pressure, which turns on and off the gas. There is another diaphragm operated from the condenser pressure which increases and decreases the amount of gas. There is another diaphragm which opens the blow-off valve.

- (1) Name of manufacturer – Copeland Products, Inc.
- (2) Address – Flint, Michigan.
- (3) Resources – This company recently took over the Electricold Company, and have authorized 200,000 shares no par value stock and claim 100,000 shares are subscribed. They have only temporary facilities now but expect to build a new factory this summer.

Mr. Copeland, who was formerly manager of the Kelvinator Corporation, left this company about two and a half years ago, and since then has been developing a machine. He has worked carefully and without much noise, as this sort of work characterized his development of the Kelvinator. When he finally got the machine to a point where he thought it was ready to market, he said that he went to Flint and personally sold \$100,000.00 worth of stock in Flint and Detroit without any selling expense, and that the development work had all been paid for before he started to sell the stock.

He stated that there was a friendly feeling between his organization and the Kelvinator Corporation, and in evidence of this showed me an agreement between himself and the Kelvinator Corporation by which he is free to use any patents now owned or which may be acquired by the Kelvinator Corporation: and that the Kelvinator Corporation is likewise free to use and patents which Copeland owns at present or may acquire. (Mr. H. R. Crane – Fort Wayne Works)

The factory is getting tooled up for production and he advised me that he contemplated producing 3000 machines yet this year. He further advised me that he had received orders for 1500 of these machines so far.

- (4) Development –
- (5) Ice making – Ice trays are placed in individual compartments, on slides. Cannot freeze fast. Easily removable. Special moulds of liberal size can be used for desserts, etc.
- (6) Size motor – 1/6 H.P. Emerson and Century motors at 1725 RPM.
- (7) Automatic or non-automatic – Automatic.
- (8) Refrigerants used – Mr. Copeland will use butane as the refrigerant for the domestic machine, and pentane for the commercial machine.
- (9) Is there a stuffing box – Yes.

He is using the same stuffing box that he used in the Kelvinator.

#2 – Copeland

- (10) How often resupplied – Unknown.
- (11) Is gas considered dangerous or not – See appendix on refrigerants.

- (12) Lubricant – The lubricant is a special lubricant that he has developed for this purpose, as the ordinary mineral oils cannot be successfully used with the refrigerants in the Marsh gas group.

- (13) Air or water cooled – Air.
- (14) Compressor – They have a single noting cylinder compressor, 2” diameter by 1 ½” stroke.
- (15) Brine tank used or direct expansion – His evaporator consists of coils of pipe in a tank, with alcohol as a cooling medium instead of brine. In order to get away from the odor of alcohol in the refrigerator he hermetically seals the cooling tank.

- (16) Retail net price to user - \$195.00 – As understood, this does not include the installation cost.
- (17) Percent discounts to central stations – Unknown.
- (18) Guarantee – Unknown.
- (19) Service –

Remarks:

Mr. H. R. Crane says that from what he knows of Mr. Copeland’s way of handling work, he would expect this machine to be a worth while competitor. There are a number of mechanical details that do not look good to him, but he believes that Mr. Copeland’s machine will probably be ranked with some of the good ones on the market.

Appendix 31

CORBLIN COMPRESSOR

- (1) Name of manufacturer – Henri Corblin, Constructor.
- (2) Address – 78 & 80, Boulevard Saint Marcel, Paris.
- (3) Resources - ?
- (4) Models - A-1
- (5) Size motor - $\frac{3}{4}$ H.P.
- (6) Dimensions:
Weight - ?
Exterior dimensions: ?
- (7) Ice making - 33 lbs. a day
- (8) Place where machine is mounted – Anywhere.
- (9) Automatic or non-automatic – It is
- (10) Air or water cooled – Water.
- (11) Water per day – 40 gallons.
- (12) Refrigerant used - ?
- (13) Compressor – Reciprocating.
- (14) Brine tank used or direct expansion – Brine tank.
- (15) Retail net price to user – Unknown.
- (16) Percent discounts to dealer – Unknown.
- (17) Guarantee – Unknown.
- (18) Is there a stuffing box – No

Remarks:

As can be seen by the picture, (Ed note: picture too dark to copy) this compressor operates through a membrane. This is an apparatus in which a thin metallic disc is clamped between two circular rings. It is oscillated and down by the pressure of oil from an oil pump. (illegible text) the refrigerating vapor through intake and discharge poppet valves. It looks to me as though the space in which this membrane is placed is curved, and it is possible that there

#2 – Corblin Compressor

curves are designed so that the membrane cannot be bent or stretched beyond its yield point, in which case the membrane might last for some time. It seems to me that this machine is quite interesting as an example of one method of getting rid of the difficulties contingent upon the use of a stuffing box.

Appendix #32

FEDERATED ENGINEERS DEVELOPMENT CORPORATION

- (1) Name of manufacturer – Federated Engineers Development Corporation.
- (2) Address – 154 Odgen Avenue, Jersey City, N.J.
- (3) Resources – These people are experimenting on a domestic refrigerating machine, but will not give out much information.
- (4) Development –
- (5) Automatic or non-automatic – Dr. Steinmetz had the impression that it would be controlled by a thermostat.
- (6) Usual temperature of ice box – They have put this machine in a standard ice box purchased at a department store and were able to maintain 35 or 40 degrees in the food compartment on a 90 degree day, but the refrigerating element, under these conditions, was run at approximately zero degrees.
- (7) Refrigerant used – Ethyl chloride.
- (8) Is gas considered dangerous or not – See appendix on refrigerants.
- (9) Lubricant – This machine will have no internal lubrication.
- (10) Air or water cooled – Water.
- (11) Compressor – This machine has a compressor, the actuating element of which is a thin membrane of goldbeater skin. On one side of this membrane is ethyl chloride which is used as the refrigerant. Water pressure is intermittently admitted to the other side of this membrane.
- (12) Retail net price to user - \$150.00.

This machine can be made for about \$50.00.
If electrically operated, it will cost a little more.

- (13) Guarantee – Unknown.
- (14) (illegible text)

FREEZERATOR

- (1) Name of manufacturer – Household Utilities Corporation.
- (2) Address – 16 Hendric Ave., Detroit, Michigan.
- (3) Resources – This Company is now owned by the City Ice and Fuel Company, of Cleveland, through which they expect to sell 5000 machines this year and 12,000 next year in Cleveland.

Mr. Bosworth, the fractional horsepower salesman of the Cleveland Office, said that this Company put out about 1000 machines last year with Masters Motors.

- (4) Size motor – ¼ H.P. repulsion induction motor.
- (5) Ice making – In the brine tank there is a compartment in which ice cubes can be made.
- (6) Automatic or non-automatic – Automatic.
- (7) Refrigerant used – Sulphur dioxide.
- (8) Is there a stuffing box – Yes.
- (9) How often resupplied – Advertisement says never.

Examination of the machine which was tested at Fort Wayne on March 5, 1923, showed that all six of the valves, and the stuffing box were leaking sulphur dioxide.

At the rate at which the machine was leaking, it would probably lose its entire charge of gas in about three (3) months.

- (10) Cost of new refrigerant - ?
- (11) Is gas considered dangerous or not –
- (12) Air or water cooled – Air.
- (13) Compressor – Three cylinder.
- (14) Place where machine is mounted – In the basement.
- (15) Brine tank used or direct expansion – Brine tank.

Freezerator brine tanks are made in three
(illegible text)
determines the size tank you need.

#2 – Freezerator

- (16) Retail net price to user - ?
The Hibbard Company have heard that the Freezerator can be made for a factory cost of \$85.00
- (17) Percent discounts to central stations – Unknown.
- (18) Does price include:
- | | | |
|--------------|---|---------|
| Refrigerator | - | No |
| Brine tank | - | Unknown |
| Installation | - | Unknown |
- (19) Average hours operated per day - ?
- (20) Estimated KW-hours per day – 2 KW-hours.
- (21) Guarantee:
ODIN - #2.
- (12) Average hours operated per day – The 15 cu. Ft. box takes about 250 watts and runs about two hours and shuts down for three.
- (13) Services – They have had some belt troubles.

Apparently they did have trouble with the freezing of oil, but by mean of an oil groove with drain, they have been able to prevent the oil from getting up into the cold part of the machine.

Remarks:

This machine is covered by patent #1,240,846, which was filed in September 21, 1915 and issued September 25, 1917. These patent papers contain a very thorough description of the machine.

The following is a brief technical analysis of their 15 cu. Ft. size.

The insulated portion of the box is about 25” x 17 ½” x 5 ft.

The total area to be insulated is, therefore, about 41.2 sq. ft.

The insulation consists of about four inches of cork-board. I estimate that with a 40 degree food compartment temperature and a 70 degree room temperature, there would be a flow of 81.5 B.t.u. per hour through this in-

sulation. The engineer of the Automatic Refrigerating Company told me that the pressure never when about 10 lbs. Gauge. I estimate that the air goes to the expansion motor at 10 lbs. gauge pressure and 140°F., where it is expanded to minus 6.7 lbs. gauge pressure and 25 degrees below zero Fahrenheit. The expansion horsepower is .324. The air then warms up to about minus 8 ½ degrees Fah., taking heat from the ice box. It is then compressed to 10 lbs. gauge and approximately 162°F. This requires a compression horsepower of .336.

The air s then cooled from 162° to 140°, after which it is re-expanded. Of course, the above figures are largely guess-work, because the Automatic Refrigerating Company would not give me all these details.

Guarantee

“This is to certify that Freezerator, Serial No._____, has been fully tested, and we hereby guarantee same against all defective material and workmanship for a period of one year from the date of purchase. Defective parts will be replaced FREE of charge if the same are prepaid to the Freezerator Co., Detroit, U.S.A.”

- (22) Service – Freezerator is assembled in independent units. Should repairs or replacements ever be necessary, they can be made without interrupting refrigerating service.

Freezerator can be removed from refrigerator and premises in a half hour's time without harm to either. This is important for those who are leasing their homes.

With the regular inspection which we are prepared to give, a Freezerator should serve you indefinitely. Parts will have to be renewed, but only at long intervals. It is the long life of Freezerator that makes its first cost insignificant. (All the above was taken from the Freezerator Bulletin.)

In the test which was held in Fort Wayne on March 5, 1923, it was found that it was almost impossible to properly adjust the expansion valves. This is one of the faults inherent in a diaphragm type expansion valve.

- (23) Noise – The machine is of light weight, but it is very noisy, the moving parts being badly out of balance.

APPENDIX NO. 34

FRIGIDAIRE

- (1) Name of manufacturer – Delco Light Co. – (FRIGIDAIRE)
- (2) Address – Dayton, Ohio. (New York Office Domestic Electric Co., Inc., 45 Warren Street.)
- (3) Resources – General Motors Company.

The following is quoted from a letter by
Mr. Edwin L. Rich of the Patent Department:

“While in Dayton, I had no opportunity to talk to anybody in Delco Light with reference to Frigidaire refrigerating machines. I did talk with Mr. R. D. Howell, of the patent department of the Dayton Engineering Laboratories Corporation, on the subject of this refrigerating machine. He said the greatest objection to refrigerating machines was the question of noise and expense. He said the operation of them was bound to be noisy, and the ordinary household refrigerator could not be sold for less than \$500.00, which made the same too expensive for the ordinary household. He also told me that Delco Light lost money in the manufacture and sale of their refrigerating machines up to about two years ago, when Mr. Grant was made president of the company and put in charge of the sale of these machines. Since that time, although they have not made any money on the refrigerating machines, they are not losing money. He says that Mr. Grant is a very energetic person, and looks after the details of the company and follows the sales work very closely.”

Mr. T. I. Vance in his paper, “Household Electric Refrigeration”, which was published in October, 1922, says that there are 5000 Frigidaire refrigerating machines which have been in successful operation for at least twelve consecutive months.

Mr. Wilson, the Albany agent of the Frigidaire, lays that there are approximately 15,000 Frigidaire in service altogether.

There are 300 Frigidaires in the city of Atlanta. (M. M. Querey – Atlanta)

Frigidaire Corporation, Dayton, Ohio, sold during 1922 approximately 2000 machines. All of these machines were equipped with Century and Wagner motors. (R. J. Druhot – Dayton)

#2 - Frigidaire

- (4) Size motor – ¼ H.P.
Motor – Alternating Current – 110 or 220 volt, single phase.
25-30-50-60 cycles. Direct Current – 32, 110 or 220 volt.
Speed – 1420 to 1750 r.p.m., according to type of motor.

The Delco Light Company are buying almost exclusively Century motors at the present time, but expect to make their own motors in the near future.

- (5) Automatic or non-automatic – Automatic.
(6) If thermostatic control, give range of temperature – Brine, 16° to 24°, 8° range.
(7) Refrigerant used – Sulphur dioxide.

Mr. Grant mentioned that the manufacturing of these machines is a very fussy job. They distill their SO₂ in order to get the moisture out of it, and they pump the air out of the system down to one-tenth of an inch pressure before charging.

- (8) Is there a stuffing box – Yes.

Mr. Grant says that they did have a great deal of trouble with their stuffing boxes, but they put two engineers on that problem and solved it about a year and a half ago. They now feel that it should not be necessary to renew the gas more than every two or three years. One of his engineers claimed that it would not be necessary to renew the gas more frequently than every five years.

The success of their stuffing box lies in a special packing material which they have developed.

Mr. Grant said that the Delco Light Company have a method of eliminating the stuffing box, but their stuffing boxes are so good that they are not sure it is worth while or necessary

- (9) How often resupplied – Indefinite.
(10) Cost of new refrigerant – Complete charge 10 lbs., present price 35¢ per lb.
(11) Is gas considered dangerous or not – Not (See appendix on Refrigerants.)
(12) Safety shut-off – Excess pressure device breaks motor circuit at 80 to 90 lbs. per square inch, pressure.

- (13) Air or water cooled – Water.
The Frigidaire Corporation is considering an air cooled machine for mounting in the cellar.
Mr. Grant expects to use SO₂ in his Air cooled machine and does not expect any trouble with oil. However, he did mention that the oil might carbonize at the higher temperature in the air cooled machine.
Mr. Grant told me that the Delco Light Company would never have put a water cooled machine on the market if the General Motors had not given them a water cooled machine. They are now developing an air cooled outfit.
- (14) Compressor – Reciprocating, two cylinder.
- (15) Brine tank used or direct expansion – Copper brine tank.
- (16) Retail net price to user.
The price of the Frigidaire includes plumbing, but sometimes an extra charge is made for wiring. (Mr. Grant says that the distributor usually includes plumbing in his price to the customer.)
- (17) Percent discounts to Distributor – 25%.
The salesman gets \$50.00 a week and 5 percent commission. This amounts to about a total of 20 percent.
In the past, the Delco Light Company has gone fifty-fifty with the distributor on advertising costs.
The Delco Light Company uses neither dealers nor central stations. The Philadelphia distributor has about ten salesmen who make house to house campaigns.
- (18) The Frigidaire machine is not made as one complete unit. Connections have to be broken whenever it is removed from the ice box. They are considering a complete unit, which might be returned to the factory for repairs without breaking and connections.
- (19) Guarantee – One year against defective material and workmanship.
- (20) Second hand business – The Delco Light Company does not do any second hand business.

- (21) Service – After the machine is sold, two adjustment calls are necessary and three other service calls are necessary, making a total of five calls during the first year. They expect the present design of the machine to last about ten years and that the gas will have to be replaced every five years.

Mr. Wilson, the Albany agent of the Frigidaire Corporation, said that out of the 1000 machines in the New York District, they have averaged two visits a machine in the last year. Most of the trouble was with the float valve in the condenser, and this has been corrected. They also had some trouble with the repacking of stuffing boxes. There is a slight odor when the packing of the stuffing box wears out.

They used to have trouble with their thermostats. The gas in the thermostat was odorless, and there was no way of testing for a leak. They now use SO₂ in the thermostat, and it is much easier to find leaks.

The machine would not operate successfully if the cooling water was over 70°F. The machines take about 10 to 20 cu. Ft. of water per day.

Mr. R. M. Bussey of our Atlanta Office writes me that the Frigidaire Corporation in the City of Atlanta gave him the following information:

“They tell me that they have in operation approximately 300 machines, and that one service man (the majority of whose time is occupied on other things that they handle, such as the Delco Light) is amply able to take care of the servicing of these machines. They figure that they receive about three calls per week for service on Frigidaires. They have an automatic switch which cuts off the water when the motor shuts down and an additional automatic pressure limit which shuts the motor off in case the machine starts without cooling water. They say that they have no trouble whatsoever from this combination.

“The Frigidaire has by far given the best account of itself of any of the machines that I have seen, but they all have the difficulties incident to more or less unreliable automatic control. One thing that has been of particular difficulty has been the controlling of the cooling water to the condenser. Either the water would run all the time, even when the machine was shut down, or else would not cut on when the compressor was started.”

APPENDIX NO. 34

FRIGIDAIRE

Mr. D. W. Weed tells me that previous to last year, the Frigidaire Company had sold 12,000 machine. Last year, they sold 1500: this year they expect to sell 5,000, and they are increasing their factory capacity in the hope of selling 25,000 next year. He says he has this information from a very good authority.

Mr. Weed further states that he understands the General Motors feel that there is a bigger field for domestic refrigerating machines than for automobiles.

APPENDIX NO. 34
FRIGIDAIRE

- (1) MODEL – B-R will be sold for use with anybody's ice box.
- (2) Cubic Contents – Suitable for boxes having a total of 18 cu. Ft., including the ice compartment.
- (3) Dimensions:
Weight – 355 lbs.
Total capacity – 18 cu. Ft. including ice chamber.
Dimensions of Refrigerator Unit – 16" high: 29" wide: 21" deep.
Overall Dimensions of Vertical Brine Tank – 16 ½" high: 16 ½" wide: 16 ½" deep.
- (4) No. cubes per tray – 24.
- (5) Size cubes – 1 ½ x ½ x 1 ½.
- (6) Ice making – Vertical Tank - 72 cubes in 3 trays; a total of 9 lbs. Horizontal Tank – 48 cubes contained in 2 trays; a total of 6 lbs. Freezing time, maximum of 8 hours.
- (7) Place where machine is mounted – Cellar.
- (8) Usual temperature of ice box - ?
- (9) Cu. Ft. water per day – 10 to 20.
- (10) Retail Net Price to user - \$295.00 (?)
(F.o.b. Dayton)
- (11) Does price include:
Refrigerator - No
Brine tank - Yes
Installation - No
- (12) Percent Operating Time – 20% to 25% in 70 degree room.
- (13) Average hours operation per day - ?
- (14) Estimated KW-hours per day - ?
- (15) Quiet operation – Compressor unit mounted on special 3-point suspension, which eliminates noise and vibration.

APPENDIX NO. 34

FRIGIDAIRE

- (1) MODEL – B-5 The 5 cu. Ft. machine is just like the 15 cu. Ft. machine except that the ice box is smaller and the cooling unit is smaller.
- (2) Cubic Contents – 5 cu. Ft.
- (3) Dimensions:
Weight – 695 lbs.
Total outside volume – 28 cu. Ft.
Exterior Dimensions – 61” high x 32” wide x 24 ¾” deep.
Interior Dimensions – Food compartment – 23 7/8” wide x 15 7/8” high x 18 5/8” deep.
- (4) No. cubes per tray – 24.
- (5) Size cubes – 1 ½ x ½ x 1 ½.
- (6) Ice Making – 48 cubes contained in 2 trays; a total of 6 lbs.
Freezing time, maximum of 8 hours.
- (7) Place where machine is mounted – Under refrigerator.
- (8) Usual temperature of ice box - 38° to 46° F.
- (9) Cu. Ft. Water per Day – 10 to 20.
- (10) Retail Net Price to User - \$495.00 (?)
- (11) Does price include:
Refrigerator - Yes
Brine Tank - Yes
Installation - No
- (12) Percent Operating Time – 15 to 25 percent in 70 degree room.
- (13) Average hours operated per day – 6 to 8.
- (14) Estimated KW-hours per day – 1.
- (15) Description of insulations – Sturdy, construction; 2- inch corkboard insulation; exterior shell, paneled with laminated wood. Finish, ivory white enamel or natural. Lining, white porcelain enamel.
- (16) Quiet operation – Compressor unit mounted on special 3-point suspension which eliminates noise and vibration. Mechanical unit enclosed in lower section of cabinet.

APPENDIX NO. 34

FRIGIDAIRE

- (1) MODEL – B-9.
- (2) Cubic Contents – 9 cu. Ft.
- (3) Dimensions:
Weight – 835 lbs.
Total Outside Volume – 37.5 cu. Ft.
Exterior Dimensions – 67 ¼” high x 39” wide x 24 ¾” deep.
Interior Dimensions – Large Food compartment – 38 ¾” high;
14 ¾” wide; 18 ½” deep. Small Food Compartment –
15 ¼” high; 16 ½” wide; 18 ½” deep.
- (4) No. cubes per tray – 24.
- (5) Size cubes – 1 ½ x ½ x 1 ½.
- (6) Ice Making – 72 cubes contained in 3 trays; a total of
9 lbs. Freezing time, maximum of 8 hours.
- (7) Place where machine is mounted – Under refrigerator.
- (8) Usual temperature of ice box - 38° to 46° F.
- (9) Cu. Ft. Water per Day – 10 to 20.
- (10) Retail Net Price to User - \$595.00 (?)
- (11) Does price include:
Refrigerator - Yes
Brine tank - Yes
Installation - No
- (12) Percent operating time – 20 to 25 percent in 70 degree room.
- (13) Average hours operated per day – 6 to 8.
- (14) Estimated KW-hours per day – 1 ½.
This figure was given me by Mr. Grant,
President of the Delco Light Company.
- (15) Description of insulation – Integral frame construction; 2-inch
corkboard insulation; shell of 5-ply laminated wood; finish,
ivory white enamel or oak. Lining, white porcelain enamel.
- (16) Quiet operation – Compressor unit mounted on special 3-point
suspension, which eliminates noise and vibration. Mechanical
unit enclosed in lower section of cabinet.

APPENDIX NO. 34

FRIGIDAIRE

- (1) MODEL – B-15.
- (2) Cubic Contents – 15 cu. Ft.
- (3) Dimensions:
Weight – 950 lbs.
Total outside volume – 56 cu. Ft.
Exterior Dimensions – 67 ¼” high x 59” wide x 24 ¾” deep.
Interior Dimensions – Right and Left sides – 38 ¾” high;
14 ¾” wide; 18 ½” deep. Small Food Compartment –
15 ¼” high; 19 ½” wide; 18 ½” deep.
- (4) No. cubes per tray – 24.
- (5) Size cubes – 1 ½ x ½ x 1 ½.
- (6) Ice making – 72 cubes contained in 3 trays; a total of
9 lbs. Freezing time, maximum of 8 hours.
- (7) Place where machine is mounted – Under refrigerator.
- (8) Usual temperature of ice box - 40° to 48° F.
- (9) Cu. Ft. water per day – 20 to 30.
- (10) Retail Net Price to User - \$775.00 (?)
- (11) Does price include:
Refrigerator - Yes
Brine tank - Yes
Installation - No
- (12) Percent operating time – 35 to 40 percent in 70 degree room.
- (13) Average hours operated per day – 8 to 10.
- (14) Estimated KW-hours per day – 1 ¾.
This figure was given to my by Mr. Grant,
president of the Delco Light Company.
- (15) Description of insulation: Integral frame construction; 2”
and 3” corkboard insulation; shell of 5-ply laminated wood;
finish, ivory white enamel or oak. Lining, white porcelain
enamel.
- (16) Quite operation – Compressor unit mounted on special 3-point
suspension, which eliminates noise and vibration. Mechanical
unit enclosed in lower section of cabinet.

Appendix 35

FRIGIDOR

- (1) Name of manufacturer – American Balsa Refrigerator Corporation.
- (2) Address – 152nd & Exterior Streets, New York City.
- (3) Resources – This company has a paid in capital of \$60,000,000. It is owned by the American International Corporation which is capitalized at \$50,000,000.00. It is interesting to note that among the directors of the latter is Cay H. Tripp of the Westinghouse Company.

Mr. T. I Jones in his paper, "Household Electric Refrigeration", which was published in October, 1922, says that there are 150 Frigidor Refrigerating Machines which have been in successful operation for at least twelve consecutive months. But I understand from Mr. Lloyd that there are only about 45 out in service.

- (4) Development – Mr. R. McA. Lloyd, a consulting engineer who is connected with the American Balsa Company in the design of the Frigidor, spent \$150,000.00 on the development of the Frigidor machine. He sold this development to the American International Corporation for \$50,000.00 and a contract for one percent royalty.
- (5) Model – 6F.
- (6) Size motor – 1/3 H.P. They are using Wagner motors at present.
- (7) Cubic contents – 16 cu. Ft.
- (8) Trays – 4.
- (9) No. ounce per tray – 12.
- (10) Size cubes – 1 ½" diameter by 1" thick.
- (11) Ice making – They can make ice very easily in this machine, in spite of the fact that there is no brine tank, but making ice increases the power consumption.
- (12) Automatic or non-automatic – Automatic.
- (13) Place where machine is mounted – Under refrigerator.
- (14) (Text illegible)
- (15) Usual temperature of ice box – 32°F.

#2 – Frigidor

- (16) Refrigerant used – Methyl chloride.
Mr. Lloyd said that they had spent \$10,000.00 in obtaining a reliable methyl chloride supply, but that this had been solved.
Mr. Lloyd mentioned that the vapor pressure of methyl chloride is about equal to the number of degrees Fahrenheit.
Mr. Kossatz says that they use methyl chloride instead of ethyl chloride because only one-fifth the displacement is necessary.
Mr. Kossatz also mentioned that he mixes the refrigerant, one pound of ethyl chloride to seven pounds of methyl chloride. This reduces the discharge pressure about four or five pounds.
- (17) Is there a stuffing box – Yes.
The stuffing box of the Frigidor machine consists of two ground, cast iron rings, one of them supported on a leather diaphragm pressed together by a spring. Any glycerine that gets through is dry and they have had very little trouble with corrosion.
- (18) How often resupplied – Yearly.
- (19) Cost of new refrigerant - \$5.00. This figures \$.63 per lb.
- (20) Is gas considered dangerous or not – Not (See appendix on refrigerants.)
- (21) Lubricant – Mr. Lloyd said they could use oil with their methyl chloride in the Frigidor, but it forms an emulsion. They have found that glycerine and graphite works better.
Mr. Lloyd also said that he found it necessary to distill all the glycerine because commercial glycerine has impurities in it, especially water.
The Frigidor Company have a glycerine seal over their stuffing box.
- (22) Air cooled or water cooled – Air.
The Frigidor machine is an air cooled outfit, Completely enclosed except for an inlet and outlet for air.
- (23) Compressor – Two cylinder, reciprocating.

#3 – Frigidor

The Frigidor Corporation have bids from the Ingersoll-Rand Company to make their pumps for \$50.00 each.

The compressor has small poppet valves with springs.

Mr. Lloyd said that they would go to a single cylinder compressor if it was not for the starting torque. (It occurs to me that this could be overcome by means of a clutch pulley, or a spring coupling, but I did not say so to Mr. Lloyd.)

- (24) Brine tank used or direct expansion – Direct expansion.
- (25) Retail net price to user - \$600.00.
- (26) Present discounts to central stations – 10%.
- (27) Does price include:
 - Refrigerator - Yes
 - Brine tank - No
 - Installation - Yes

- (28) Average hours operated per day – 8 hours.

There is no brine tank and the machine will run about fifteen minutes on and forty-five minutes off, defrosting each time.
- (29) Estimated KW-hours per day – 3 KW-hours. (T. I. Jones)

The machine takes about 4 KW-hours on the hottest day, but averages about 2 ½ KW-hours.
- (30) Description of insulation –
- (31) Second hand business –
- (32) Guarantee – Six months.
- (33) Service – Mr. Kossatz, the service manager of the Frigidor Company, says that they have redesigned their compressor. It is now a two cylinder, single acting compressor with a gear inside the crankcase. The (Text illegible) has a Micarta Herringbone pinion. They do not expect any trouble from the methyl chloride and glycerine eating the Micarta. With their new compressor, they expect to use the (Text illegible) raw-hide supported, cast iron contact in place of a stuffing

#4 – Frigidor

box. They cover the rawhide with copper in order to prevent to methyl chloride from destroying the rawhide.

They have quite a fancy oil separator consisting of baffles, etc., but even so, they have had trouble with the glycerine clogging the float expansion valve. Whenever this happened, it was necessary to open a blow-off cock in the float chamber in order to let off non-condensable gases. This allows the float to rise sufficiently so that the pressure could blow the glycerine through the valve seat. Having had so much of this trouble, they have put in a very small leak from the top of the float chamber to the suction side. This decreases the efficiency of the machine, but allows the non-condensable gases to leak off. Since making this change, they have had no more trouble with their float valves.

The Frigidor Company have forty-five of their machines out and they had 104 service calls last year. Only one of these had to do with the stuffing box. Most of these service calls were relay troubles. Quite a number of the service calls were in order to fix the float valve. Also, quite a number of these calls were only “foolish” calls.

Mr. Lloyd says that their troubles have been chiefly with motors and belts.

FRIGOR

- (1) Name of manufacturer –
- (2) Address – 3. Rue Gretry, Paris.
- (3) Resources - ?
- (4) Models – Two (small and large)
- (4-B) Size motor – No motor used.
- (5) Ice making – Small; In one heating one kilogram 500 grams
(in three blocks or in one) of ice can be made.
Large: In one heating three kilograms (in
three blocks or in one) of ice can be made. (One kilogram =
2.2 lbs.)
- (6) Place where machine is mounted – Anywhere.
- (7) Automatic or non-automatic – Non-automatic.
- (8) Air or water cooled – Water.
- (9) Refrigerant – Ammonia but the name of the absorption agent
is not given.
- (10) Place where machine is mounted – Anywhere.
- (11) Is there a stuffing box –
- (12) How often resupplied – Indefinite.
- (13) Retail net price to user – Small; Machine- 650 francs.
Box - 70 “
Large; Machine - 750 “
Box - 75 “
- (14) Percent discounts to dealer – Unknown.
- (15) Guarantee – Unknown.

Remarks:

This seems to me to be exactly the same machine as was marketed last year by the Karge Laboratories, and was later shown to be more or less of a “fake”. The
(Text illegible)
pail containing water and heat the generator with a gas jet until the automatic indicator rises. Then, one ceases to heat and takes the condenser out of the water and places the generator in the water. They state that an intense cold of 30 degrees below zero Centigrade can be produced and that

#2 – Frigor

in one heating of several minutes, three blocks of ice of one kilogram each can be made. This corresponds to 6.6 lbs. of ice. I guess this is probably possible. The trouble with the Karge Laboratories' machine was that they advertised that one operation would keep the ice box cold all day. It is obvious that 6.6 lbs of ice could not keep as ordinary sized ice box cold all day.

FRIGORE

- (1) Name of manufacturer – Carbone Company, Inc.
- (2) Address – 173 Lafayette Street, New York City.
- (3) Resources – The advertisement says that Frigore has been constantly improved by experiments and practical use and is now in its eleventh successful season.
- (4) Models – Fr. I Fr. II.
- (5) Cubic contents –
- (6) Dimensions:
Weight - ?
Total outside volume - 45 cu. Ft. 135 cu. Ft.
Exterior dimensions - Height – 55” Height – 69”
Depth - 29” Depth - 39”
Width - 49” Width - 97”
- (7) Ice making – 10 to 20 lbs. of clean crystal-white ice can be produced at the same time.
- (8) Automatic or non-automatic – Non-automatic.
- (9) Place where machine is mounted – Outside refrigerator.
- (10) Refrigerant used – Carbonic-anhydride.
- (11) How often resupplied - ?
- (12) Cost of refrigerant - ?
- (13) Is gas considered dangerous or not – The advertisement says that carbonic-anhydride is safe, harmless and without any odor.
- (14) Air or water cooled –
- (15) Brine tank used or direct expansion –
- (16) Guarantee – Unknown.
- (17) (Text illegible)
marketed in this country by the above concern.

Frigore #2

Remarks:

A recent letter states that these machines have been manufactured in Switzerland, but that this Company is now fitting up a factory in this country for manufacturing and it will be some time before they are ready to sell their machines.

- (1) Name of manufacturer – Glacifer Company.
- (2) Address – 491 Main Street, Cambridge, Mass.
- (3) Resources – This machine is a development of Dr. Elihu Thomson's which is being tried and tested at the Glacifer Company.
- (4) Models –
- (5) Ice making – It is contemplated that where ice itself is needed the evaporator shall be extended downward into an ice box and be made of such a shape that the ice is easily removed; in other words, this constitutes a little accessory tank containing the water to be frozen.
- (6) Automatic or non-automatic – Automatic.
Automatic control will be by means of freezing and melting ice and inherent unloading of the compressor at low temperatures.
- (7) If thermostatic control, give range of temperature – Professor Thomson does not expect to use a thermostat. He will have a clock which will shut the machine down at night and start it again in the morning. During the day, the machine will unload itself when it sucks a high vacuum.
No thermostat is required for two reasons. There is a tank surrounding the refrigerating part containing so much water that it is never all frozen. When this tank is nearly frozen, the conduction of heat through the ice from the outside is slow and the evaporation of the condensed SO₂ correspondingly slow, so that the pressure to be exerted by the pump in pumping is small. The empty spaces being nearly vacuous, or the sulphur dioxide in the apparatus being limited, is nearly all in the state of condensation. In other words, when there is not a great deal of cooling required, the load automatically goes off the motor.
- (8) Refrigerant used – Sulphur dioxide.
- (9) How often resupplied - ?
- (10) Is gas considered dangerous or not – See appendix on Refrigerants.
- (11) Air cooled or water cooled – Air.

#2 – Glacifer Company

- (12) Compressor – The compressor is a single cylinder, single acting compressor running at 1700 RPM. It is balanced according to the theory developed by Dr. Koss and runs with very little vibration.
- (13) Brine tank used or direct expansion – Professor Thomson expects to have a tank similar to the ordinary brine tank, which will be filled with water instead of brine. The temperature will be held at 32 degrees, due to the freezing and melting of ice in this chamber.
- (14) Retail net price to user - ?
- (15) Percent discounts to central stations – ?
- (16) Guarantee – Unknown.
- (17) Remarks:

The condenser consists of a small chimney about 5” in diameter in 1 ½ ft. high, in the center of which is a pipe about 2” in diameter with four pipes loosely wedged outside the four little pipes. The 2” pipe is connected by a lot of star shaped punchings to the outer 5” pipe. The heat from the condensation of the refrigerant causes a draft up this chimney. Professor Thomson expects to use exactly the same shape chimney, etc/. in place of expansion coils. Professor Thomson has a special form of Float valve, which is geared so that a small motion of the float makes quite a large motion of the needle valve.

The apparatus would be started in the morning, either by the hour or by signal, it being understood that during the night, since the refrigerator is kept closed, there being no special element for extra cooling, the storage or excess of cooling over the demand of the day before will be sufficient. This is, however, not to forbid the freezing of a considerable block of ice and the cutting off altogether of the apparatus until the block is melted. In other words, if the apparatus was of a little larger capacity than needed, it might be made to run and so complete ice for two or three days cooling, so that it would not have to be run everyday. This is particularly the case when the seasons are changing, as in the cooler season there would be less need of running it than there would of in the hotter seasons of the year.

Appendix 39

GOETZ ICE MACHINE

- (1) Name of manufacturer – Goetz Ice Machine Company.
- (2) Address – 675 North 12th Street, Philadelphia, Pa.
- (3) Resources - ?

- (1) Name of manufacturer – Mr. Havens (Name has been changed from Havenstrite.)
- (2) Address – Lynbrook, L. I.
- (3) Resources – The men who were promoting this machine were discouraged by a rumor that the General Electric Company were going to put a machine on the market that would sell for \$150.00. Mr. Havens is now trying to get the Ford Instrument Company interested and he is also negotiating with another concern in New York City.

Mr. Havens states that he is not tied up with any one yet, and should the General Electric Company be interested, he would be glad to take the matter up with us. He has extended a standing invitation to Mr. Crane or anyone else in the G. E. Co. who would be interested to go to Lynbrook to inspect the machine which has been running for three years without any service.
- (4) Size motor – ¼ H.P., RSA – 1725 R.P.M.
- (5) Automatic or non-automatic – They have made no attempt for providing automatic control, and there apparently was a lot of developmental work to be done before the machine would be ready for the market.
- (6) Usual temperature of ice box – Maintains a 45 degrees on hottest days.
- (7) Refrigerant used – Ethyl chloride.

Ethyl chloride expanded in the mixture producing effects and efficiency of direct expansion, with a storage means for “cold” during shut-down.
- (8) Is there a stuffing box – The machine has a stuffing box of the ordinary type.
- (9) Air or water cooled – Condenser air cooled by surface of housing. No water used except in mid-summer. Housing contains steel pipe coil as a water condenser for peak (Text illegible)
- (10) Brine tank or direct expansion – Cooling tank 12” diameter by 18” long, welded tight with dished heads. Tank partly filled with glycerine and water.

Havenstrite - #2

- (11) Retail net price to user – Unknown.
- (12) Average hours operated per day – 6 to 8 hours.
- (13) Service – There are two points brought out against the outfit. First, the stuffing box between the motor and the cylinder it was considered would leak, but Mr. Havens says that this stuffing box has worked perfectly for three years without any adjustment; second, Mr. Crane at the time he saw the machine in 1921 told Mr. Clark that before a year was up he would change his refrigerant from ethyl chloride to sulphur dioxide, but Mr. Havens still is using ethyl chloride.

Remarks:

This refrigerating machine has a square piston.
Mr. Dans, the industrial control specialist of the New York Office, said that he had not heard of the Havenstrite development for at least two years.

GEORGE HORAWA

- (1) Name of manufacturer – George Horawa.
- (2) Address – 4234 Mt. Elliot Street, Detroit, Michigan.
- (3) Resources – The following is quoted from a letter from Mr. H. E. Crane of the Fort Wayne Works:

“This man is a foreigner and probably a very good mechanic, who came over here and was employed in the experimental department of the Packard Company. At the same time the Isko Corporation was started at Detroit, he was transferred to the Isko Company and worked with the company until it left Detroit. I believe that his only knowledge of refrigeration was obtained during his work on the Isko machine

I would say that this is a hopeless proposition.”

- (4) Models – He has only built one model and has this installed in his home.
- (5) Size motor – ¼ H.P.
- (6) Refrigerant used – Sulphur dioxide.
- (7) Compressor – Single cylinder, single acting.
- (8) Place where machine is mounted – Mr. Horawa has the refrigerator in his front hall, with the machine in the cellar.
- (9) Service – The machine is very noisy. It is also very crude.

- (1) Name of manufacturer – Isko Company.
- (2) Address – 2525 Clybourn Avenue, Chicago, Illinois.
- (3) Resources – This concern is now owned by the General Motors Company, who will allow them to sell only 1000 machines for which they have the parts made up, after which they must confine their activities to servicing machines now installed.

The General Motors Company bought the Isko Company in order to get the patents. They hope that these patents will make it possible for them to keep others out of the air cooled domestic refrigerating field. All the other companies are infringing their patents at the present times.

- (4) Models – Isko No. 20.
- (5) Size motor – ¼ H.P.
- (6) Cubic contents – The household machine is capable of cooling well insulated refrigerator space of from 25 to 40 cu. Ft.
- (7) Ice making – The Isko machine makes ice cubes for table use.
- (8) Automatic or non-automatic – Automatic.

Mr. C. E. Reddig of the Western Electric Company told me that the Isko Company uses the same kind of automatic control which the Western Electric Company used to sell for furnace control. It is made by the Minneapolis Heat Regulator Company.

- (9) Usual temperature of ice box – Isko holds refrigerator temperatures around 45 degrees.
- (10) Refrigerant used – Sulphur dioxide.
- (11) Is there a stuffing box – Yes.

The stuffing box is below the level of the oil in the oil reservoir, and hence, while packed to resist gas leakage, operates against oil only (Text illegible)

- (12) How often resupplied - ?
- (13) Cost of new refrigerant - ?

#2 – Isko

- (14) Is gas considered dangerous or not – See appendix on refrigerants.
- (15) Air cooled or water cooled – water.
- (16) Cu. Ft. water per day – 12 gallons per hour.
- (17) Compressor – The exclusive principle of Isko operation is the rotary, herringbone gear compressor - - the only moving part - - running submerged in a sealed chamber of oil, eliminating all valves, belts, and other parts subject to wear, adjustment or skilled attention.
- (18) Place where machine is located – The simplest installation of an Isko machine is directly on the refrigerator. If preferred, it may be placed in an adjoining room or in the basement below the refrigerator.
- (19) Brine tank used or direct expansion – Brine tank.
- (20) Retail net price to user - ?
- (21) Percent discounts to central stations - ?
- (22) Estimated KW-hours per day – The model 20 uses 1/3 KW-hour each hour.
- (23) Second hand business – The Isko Company used to take in second hand boxes as part payment for Isko machines, but they never could sell the boxes for as much as they paid for them.
- (24) Installation – In the old days, when they were installing water cooled Iskos where plumbing was necessary, the installation charge sometimes ran as high as \$50.00 or \$60.00.
- (25) Guarantee – Unknown.
- (26) Service – Mr. G. E. Miller, sales manager of the Cleveland Illuminating Company, has had in his house an old Isko machine for four years. He is very well pleased with it. After a couple of years, the machine got loose in the bearings and had to be tightened to prevent noise. The machine was completely overhauled and he supposes the gas was renewed.

Mr. Miller says that the Isko Company burned out a great many motors in the early days, but that this was largely due to the wrong construction of the motor oiling system, so that if the motor was running in the wrong direction, the oil rings pumped all the oil out of the bearings.

#3 – Isko

The trouble with the old Isko was that the oil parts got plugged with iron sulphide, and also that oil bubbles got into the expansion valve and coils. They also had trouble with rust on the brine tank. The stuffing box lasted about two years. Thirty percent of their trouble was with the motor and control. Eighteen percent of the troubles were the iron sulphide and oil ports, and the oil bubbles in the expansion valves. The rest of the troubles were such things as rust, etc.

The Hibbard Company told me that the service of the old Isko machines was \$75.00 per machine per year.

They had no special trouble with the Isko pumps after auxiliary holes were put on to drain the oil back to the suction side of the pump.

KARGE

- (1) Name of manufacturer – Karge Laboratories.
- (2) Address – Oswego, N.Y.
- (3) Resources – These people are at present financed by Mr. Kingsford of the Kingsford Foundry and Iron Works, Oswego. They have no machinery and are occupying a building owned by Mr. Kingsford.

This Company is to be financed by Mr. Kingsford of the Kingsford Foundry and Machine Works of Oswego, a man of considerable means, and as soon as Mr. Karge is able to prove that he can accomplish what he claims to do, and can secure the approval of “Good Housekeeping” and others interested, we understand Mr. Kingsford will furnish the necessary funds to go ahead. They are now located in a building owned by Mr. Kingsford, with no machinery. (C.W. Tiffany – Syracuse.)

These people about a year ago, placed on the market a small house type refrigerating machine which did not give satisfaction swing to its impracticability and we understand that they later called in all of the units and refunded the customers’ money.

- (4) Models –
- (5) Automatic or non-automatic – Automatic.
- (6) Refrigerant used – Ammonia.
- (7) How often resupplied – The Karge Laboratories say that there is no recharging.
- (8) Is gas considered dangerous or not – See appendix on refrigerants.
- (9) Retail net price to user – Mr. C. W. Tiffany of our Syracuse Office says that this machine will retail for about \$300.00. including a refrigerator on the side.
- (10) Percent discounts to distributors – The Karge Laboratories will sell through distributors who will have exclusive selling rights for their territory whether case be the city, country or more.
- (11) Guarantee – Unknown.
- (12) Service – Mr. C. A. Larcad, sales manager of the Karge Laboratories says that their product has no moving parts, hence the matter of service does not enter in.

#2 - Karge

Remarks:

There will be two tanks about 4" in diameter and about 4 ft. high, each containing a chemical solution, one of which ammonia. As one tank approaches 210 degrees Fahrenheit it is thrown off automatically by a thermostat and the other tank started. They now use three flues in each, but only one has been necessary to accomplish the desired results in connection with the 500 watt heating units.

- (1) Name of manufacturer – Keith Electric Refrigerating Co., Ltd.
- (2) Address – 257 Campbell Avenue, Toronto, Canada.
- (3) Resources – This company was incorporated August 12, 1922, with an authorized capital of \$100,000.00, but have just re-organized and no financial statements are available. They are but little known in the credit lines so far.
- (4) Development –
- (5) Model – K-7.
- (6) Cubic contents – 7 cu. Ft., 10 ½ sq. ft. shelf area.
- (7) Dimensions:
Outside dimensions – 59” high x 32” wide x 24 ¾” deep.
- (8) Ice making – “In other electric refrigerators, ice cubes are frozen in pans, which have to be filled in the first place and then, to get the ice out, they have to be treated with hot water and the ice cubes dumped into a dish. Quite an operation to get one or two cubes:
“In the Keith Refrigerator, the ice blocks are always available by merely lifting them out of the ice container. The cups are automatically filled with water and the blocks automatically discharged into the container. If not used, any excess melts away and the water is discharged down the drain.”
- (9) Automatic or non-automatic – Automatic.
- (10) If thermostatic control give range of temperature –
- (11) Refrigerant used – Ammonia.
“Where a machine can be made entirely of steel, as in the case with the Keith, ammonia is the ideal refrigerant. It is not poisonous, explosive, or inflammable. It is condensed at moderate pressure, and is the most efficient refrigerant known, as is demonstrated by its universal use in large plants. There is not enough ammonia in the Keith
(Text illegible)
kitchen.”

#2 - Keith

- (12) How often resupplied – The ammonia remains unchanged in-
Definitely.
- (13) Is gas considered dangerous or not – See appendix on refri-
gerants.
- (14) Air or water cooled – Water.
Cu. Ft. water per day – 116 gallons a day (3500 a month).
- (15) Place where machine is mounted – In top of refrigerator.
- (16) Brine tank used or direct expansion –
- (17) Retail net price to user - \$350.00.
- (18) Does price include:
Refrigerator - Yes
Brine Tank - - - -
Installation - No

- (19) Average hours operated per day –
- (20) Estimated KW-hours per day – 2/3 to 2.6 KW-hours per day.
(70 to 80 KW-hours per month.)
- (21) Description of insulation – The insulation consists in cork-
board three inches thick. The corkboard is cemented to the
steeling lining with hot asphalt, and as every part of the
lining is covered and all cavities filled with melted asphalt
there is no possibility of existence of places in which
moisture could collect and bacteria breed.
- (22) Guarantee – Unknown
- (23) Service – Because of the absence of all moving parts, delicate
parts, springs and valves, the service cost is very low. A
yearly overhauling by an intelligent mechanic is desirable,
and this should not require more than half an hour. Free
service is given by the dealer for the first year. Should
anything to wrong with a machine, a new one can be installed
by one man in about one hour, without moving the refrigerator.

Remarks:

(Text illegible) say he connected to
the ordinary house lighting system. (Text illegible)
connections can be made to the sink in the kitchen or from
the house piping system. A plumber and electrician can do
all the work, and the average cost is about \$20.00 where per-
manent pipes and wires are installed in a house already
built. In a building under construction the cost of piping

and wiring is very small.

APPENDIX #44-A

INFORMATION FURNISHED BY MR. STUART OTTO
ON KEITH MACHINE

Mr. Otto says that the Keith machine has a 5 ½ cu. Ft. box and runs eight cycles on a hot day. There is about two pounds of ammonia in the system, and probably not more than 1 ¼ lbs. is circulated;

He did not seem to have any definite objections to the Keith machine, but said that their great claim was low cost and that if their machine was built with the same refrigerating capacity as his own, it would cost more than the Otto. He also felt that there was a disadvantage in the fact that the switching over of the Keith machine from the cooling to the heating period depended upon the melting of some ice. He felt that this let the temperature in the box rise too high.

His objections seemed to be very minor and, as a result of our conversation, my opinion of the Keith machine was, if anything, increased.

ARStevenson, Jr.DW

February 16, 1924.

KELVINATOR

- (1) Name of manufacturer – Kelvinator Corporation.
- (2) Address – 2051 Fort Street, N. Detroit, Mich., Branch office, 24 W. 40th Street, New York, N.Y.
- (3) Resources – Paid in capital \$712,000.00, and borrowed capital, \$137,000.00.

Output in 1922, \$500,000.00.

A letter from the Kelvinator Corporation states that they have been over the profit line for over a year and have sold more machines in 1922 than in their whole previous history.

Mr. North of the Electric League in Cleveland, calculated that 1800 Kelvinators could be sold a year in Cleveland. This would mean half a million dollars worth of business. He based his figures on tabulated data on the number of homes being built and the number of persons having salaries greater than \$4000.00. He estimated that there would be 50 Kelvinators sold a month for new houses and 100 Kelvinators sold a month for old houses.

The Edison Electric Illuminating Company is pushing the Kelvinator machine in Boston. They sold fifty of these last year and the Kelvinator Corporation sold one hundred. They make 150 Kelvinators in one year in Boston and vicinity.

Mr. H. M. Bussey, of the Atlanta Office, says that he understands that the Kelvinator has recently started an agency again in his district and are very actively pushing the sale of their machine. They have sold ten machines so far in Georgia district and he is told that they are
(Text illegible)

Louis district they have about 300 machines out and that they have an order 10,000 machines for the whole country.

Mr. T. I. Jones in his paper, "Household Electric Refrigeration", which was published in October, 1922, says that there are approximately 3,500 machines installed up to August 1, 1921, which have been in successful

#2 – Kelvinator

operation for at least twelve consecutive months. He also says that ninety-nine percent plus are giving satisfaction.

(4) Development –

(5) Models – (1) 06 (2) 619 (3) 1014 (4) 1420 (5) 2030 (6) 3040

There are only two sizes of Kelvinator machines.

The other sizes differ only in the size of brine tank.

(6) Size motor - 1/6 1/6 1/6 1/4 1/4 1/4

The Kelvinator Corporation use Century and

Masters motors.

(7) Cubic contents – up to 6 6-10 10-14 14-20 20-30 30-40
cu. Ft.

(8) Trays - 1 2 2 3 3 3

(10) No. cubes per tray – 21 for all.

(11) Size cubes – 1 1/2" x 1 1/2" x 1 1/2".

(12) Place where machine is mounted – In basement.

(13) If thermostatic control, give range of temperature - 4° Fahr.

(14) Usual temperature of ice box – From 38 to 50 degrees, depending upon quality of refrigerator and point at which the temperatures are taken.

(15) Refrigeration used – Sulphur dioxide, anhydrous.

The chief difficulty with the SO₂ is a fungus growth which it causes in the oil, which gums up the systems. It is necessary to pump out the compressor every once in a while and put in new SO₂ and new oil.

(16) Is there a stuffing box – Yes.

(Text illegible) 1921, Mr. H. M. Crane said that he did not believe a stuffing box (Text illegible) although the Kelvinator Corporation was spending considerable money in their stuffing box which is a special design using a sylphon bellows and genelite metal.

#3 – Kelvinator

- (17) How often resupplied – Once in three years.
 Mr. Greenwood of the Edison Electric Illuminating Company of Boston, says that new SO2 is required each year.
- (18) Cost of new refrigerant - \$1.40 for a complete renewal of charge.
- (19) Is gas considered dangerous or not – Not. (See appendix on refrigerants.)
- (20) Air or water cooled – Air.
- (21) Cu. Ft. Water per day – None.
- (22) Compressor – Reciprocating, two cylinder single acting.
- (23) Brine tank used or direct expansion – Brine tank.

Mr. T. I. Jones of the Brooklyn Edison Company, says that he feels that the Kelvinator Corporation did not return to the brine tank for engineering reasons, but as a commercial blind to overcome the bad reputation of their direct expansion machine.

Mr. V. R. Greene says that the old Kelvinator was a direct expansion machine, whereas, the new Kelvinator has a brine tank. He feels that the old Kelvinator was better. There was a high velocity through the expansion coils which kept them free from oil.

- (24) Retail net price factory, from Mr. T. I. Jones' paper –
- | | | | | | |
|----------|----------|----------|----------|----------|----------|
| \$195.00 | \$225.00 | \$250.00 | \$300.00 | \$350.00 | \$395.00 |
|----------|----------|----------|----------|----------|----------|

A local dealer in Schenectady quotes on the Kelvinator as follows:

<u>Capacity</u>	<u>Price</u>
0 to 6 cu. Ft.	\$255.00 plus installation
7 to 10 cu. Ft.	287.00 “ “
11 to 14 cu. Ft.	313.00 “ “

The following (Text illegible) taken from an up-to-date price list sent to me by Mr. C. K. Nichols of the New York Edison Company:

\$235.00	\$265.00	\$290.00	\$340.00	\$390.00	\$435.00
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#4 – Kelvinator

(25) Percent discounts to central stations – On dealership and sales connections only.

(26) Does price include:

Refrigerator –	No	No	No	No	No	No
Brine tank -	Yes	Yes	Yes	Yes	Yes	Yes
Installation -	No	No	No	No	No	No

The Hibbard Company, agents for the Kelvinator in Cleveland, say that the average installation charge on a Kelvinator is about \$22.00. This does not include a drain for the melted frost. It is assumed that this drain would be there for an ordinary refrigerator.

Mr. Rogers of the Sauter Company, Schenectady, says that here in Schenectady the electrical wiring for a Kelvinator costs about \$65.00. The wiring from the Kelvinator to the motor is \$30.00. The meter box is \$12.50, and the wiring from the meter box to the pole is about \$22.50.

The Hibbard Company is willing to put Kelvinators in 90 percent of the boxes which people have in their houses. They guarantee to keep the brine tank twelve to fifteen degrees colder than ice.

Mr. A. C. Greenwood of the Edison Electric Illuminating Company, who are the agents for the Kelvinator in Boston, says that 50 percent of the boxes which they examine are suitable for use with an automatic machine.

The Kelvinator people are willing to sell their machines separately from the ice box and find that about 50 percent of the ice boxes in peoples' houses are suitable.

(27) Average hours operated per day – 8 hours.

(28) Estimated KW-hours per day –

1.6 1.6 1.6 2.4 2.4 2.4

Mr. V. R. Greene thinks that his Kelvinator takes about 3 KW-hours and that in summer he has a special rate of 3 ½ cents with a minimum meter charge of \$2.00
(Text illegible)

(29) Guarantee – One year.

The Hibbard Company sells the Kelvinator with a three months' guarantee. After then, they sell a thirty day inspection service at \$25.00 per year.

#5 – Kelvinator

(30) Noise –

When Kelvinators are installed in apartment houses, the machinery is sometimes hung from brackets in the ventilating shaft in order to avoid noise.

Mr. Greene feels that the noise of the Kelvinator is very much less disagreeable than that of the Frigidaire because it comes so much faster.

- (31) Service – Mr. R. H. Bussey of the Atlanta office, says that he is informed that it is believed that one man can take care of the servicing of 500 Kelvinator outfits. They say that they only have a call about twice a year for each outfit and that the troubles are generally due to blown fuses or some minor motor trouble. He is further told that the Kelvinator will operate satisfactorily as high as 135 degrees Fahrenheit room temperature and that they have had no trouble whatever from hot weather. They state that they have a large number of machines in Texas where summer temperatures ran up as high as 95 to 100 degrees Fahrenheit, and that they are experiencing no trouble whatever from this source.

There is some trouble with slipping of the belt on the Kelvinator. One man told me that in three or four years he had burned out about six belts a year. I believe that the Kelvinator has to replace the sulphur dioxide about once a year.

Mr. Koken told me that the Kelvinator has leaky fittings.

Mr. Kimnerman has heard that the expansion valve has a tendency to gum up.

Mr. V. H. Greene has a Kelvinator in his home. A short time ago an idler pulley froze, after squeaking for two hours, and burned the belt. It took four days to get another belt. He burns his belt up about six times a year because sometimes when the machine tries to start too soon after it has shut down, before the pressures are equalized, the belt slips. He, therefore, feels that a machine of this sort should be direct connected instead of belted. He also believes that two or three service calls a year would be necessary each year to keep a Kelvinator in order.

(Text illegible) of the Kelvinator Corporation,

stated that they only have 1.9 service calls per machine per year. He also said that 50 percent of the service calls are unnecessary, foolish questions. They have 12,000 machines out altogether; 1500 machines in the city of Detroit. In Detroit, there are eight service calls a day, which are easily handled by two service men.

#6 – Kelvinator

The Edison Electric Illuminating Company of Boston does not attempt to service the Kelvinators which they sell, but the Kelvinator Corporation gives free service for three months.

During the last year, the Hibbard Company have had no trouble with the thermostats on the Kelvinator, but they still have trouble with the expansion valve and a great deal of trouble with cracked fittings on pipes due to heating and cooling. They also have a great deal of trouble with soldered joints on the brine tank. They insist there is no trouble with leaky stuffing boxes. They feel that there is an advantage in the belted unit in that it is cheaper to burn up a belt than to burn up a motor.

Perhaps once a year they have to change the valves of the Kelvinator because they become noisy. They have had practically no complaint of smells deposited on the brine tank. They feel that the defrosting washes these off.

The salesman for the Servel was a Mr. Miller, who used to be with the Kelvinator Corporation. He had seen Kelvinator pistons badly corroded due to moisture in the sulphur dioxide.

The Kelvinator Corporation sell their machines only within reach of a Kelvinator Service Station.

PROFESSOR KEYS' MACHINE

- (1) Name of manufacturer – National Automatic Refrigerating Company.
- (2) Address – 564 First Street, South Boston, Mass.
- (3) Resources – Professor Keys has had one machine which has run for nine months.

They have already built ten or twelve of these machines.

This absorption machine avoids the difficulties that have been encountered with almost all other types of absorption machines because the absorbent is solid. Professor Keys has found a solid absorbent which is many thousand times as good as powered charcoal. He has had some of these machines out in the homes of his friends for about a year and they have worked very successfully.

- (4) Development –
- (5) Automatic or non-automatic – It is automatic in that it works from a float switch in the liquid reservoir.

During the heating period, the ammonia is driven off through a non-return valve through the condenser into a liquid receiver. When the level in the liquid receiver has reached a certain point, a float switch cuts off the electric heating coil and by means of a two way solenoid (Text illegible) valve, turns the water from the heater into the generator. The gas is then allowed to expand in the expansion coils and is sent back into the cold generator through a non-return valve. When the level in the liquid receiver has drawn down, the float switch again reverses the cycle.
- (6) If the thermostatic control, give range of temperature – No thermostat is used.
- (7) Refrigerant used – Pure anhydrous ammonia.
- (8) How often resupplied – Unknown.
- (9) Cost of new refrigerant – Unknown.
- (10) Is gas considered dangerous or not – See appendix on refrigerants.

#2 – Professor Keyes' Machine

- (11) Air or water cooled – Water
- (12) Cu. Ft. of water per day – The water runs all the time and consumes about 72 gallons a day.
- (13) Retail net price to user – Unknown.
Professor Keyes believes that this machine can be built for a factory cost of \$30.00 or \$40.00.
- (14) Average hours operating per day – This machine operates about one hour heating and three hours expanding, making about six cycles a day.
- (15) Estimated KW-hours per day – 3 KW-hours.
- (16) Safety shut-off – There is a fusible link attached to the generator so that if the temperature goes above 100 degrees Centigrade, the power will be cut off. There are also a pair of contacts on a pressure gauge which will make a short circuit, blowing the fuse in case the pressure goes over a certain amount.
- (17) Guarantee – Unknown.
- (18) Service – The two chief objections to this machine are that it uses ammonia, against which there is a public prejudice on account of accidents in large ice plants; and, it also requires water cooling.
- (19) Patents – 1,277,085
1,293,469
1,258,017
1,267,772

APPENDIX #46-A
INFORMATION FURNISHED BY MR. STUART OTTO
ON KEYES MACHINE

The Keyes machine has 750 watt heating units and runs six to eight cycles a day, of 50 minutes each. The average of this is seven cycles, or 5.83 hours' operation a day of 750 watt units, which is about 4.4 KW-hours a day. During the heating period, the water runs at the rate of 30 gallons an hour. This is equivalent to 176 gallons of water per day through the condenser. During the cooling period, the water runs at the rate of 16 gallons an hour through the absorber. This is equivalent to 190 gallons of water per day through the absorber. This makes a total of 366 gallons of water. When I was in Boston, Professor Keyes told me that they only took 72 gallons a day and I said, in my earlier report, that this was unbelievable. Mr. Otto's figure which he says he got from their test charts when he visited their factory, seems much more likely.

Mr. Otto's figure of 4.4 KW-hours a day also seems much more likely than the 3 KW-hours per day which Professor Keyes mentioned to me.

Mr. Otto says he understands that Professor Keyes' secret solid absorbent is some form of silver nitrate, which would be expensive. He feels that the heat of absorption of ammonia vapor in Professor Keyes' machine in the solid absorbent is much higher than the heat of absorption of ammonia in water and, therefore, Professor Keyes' machine should be less

(2)

efficient that the Otto.

Mr. Otto also says that the Keyes machine has a float valve in the ammonia liquid container and another float valve in the water system. He feels that these float valves and the two non-return valves in the ammonia system are likely to cause trouble. The Otto machine has no valves at all or moving parts in the ammonia system, and only one three-way valve in the water system.

ARStevenson, JR-DW
February 16, 1924.

- (1) Name of manufacturer – Knickerbocker and American Ice Co.
- (2) Address –
- (3) Resources – Mr. Reuschline, superintendent of Plants of Knickerbocker and American Ice Company, says that within six months he expects to put on the market a domestic refrigerating machine.
- (4) Cubic contents – Will make 50 lbs. of ice a day.
- (5) Refrigerant use – Unknown.
The refrigerant will be enclosed in a brass knob mounted on the refrigerator.
- (6) Retail net price to user – Between \$200.00 and \$300.00 for The refrigerating box with the equipment.

Appendix 48 KOLD KING

- (1) Name of manufacturer – Kold King Corporation.
- (2) Address – Office: 8292 Woodward Avenue, Toledo, Ohio;
Factory: corner of Harper and Hastings Streets, Toledo, Ohio.
- (3) Resources – The following is quoted from a letter from Mr. A. A. Shirley of the Detroit Office:

“We were told that Mr. Fred Hersee is selling the machine in New England and is located at 248 Boylston Street, Room 516, Boston, Mass. There are, we understand, approximately 20 machines in and about Boston.

“After seeing what we have of the troubles of other ice machine manufacturers, we could not feel that this Company has entirely solved its difficulties, and in fact we believe that they have not so nearly reached their goal as have some other Companies such as the Kelvinator Corporation and Freezerator Company, both of which are in this city. As near as we could find out, the Co. has about 100 machines total, installed.”
- (4) Development –
- (5) Size motor – This machine is driven by an 1/6 H.P. Leland or Masters motor, at 1725 R.P.M.
- (6) Cubic Contents – The machine is designed for ice boxes which have no more than 20 cu. Ft. capacity, and is supposed to cover 90 percent of those being made.
- (7) Automatic or non-automatic – Automatic.

For control, the arrangement is different from that which most manufacturers use. If the temperature in the ice box goes up to a certain point the gas expands and opens the needle valve which is connected from a small pipe to the outside pressure switch located near the motor. This switch closes and starts the equipment.
- (8) Refrigerant used – Sulphur dioxide.
- (9) How often resupplied – Unknown.
- (10) Cost of new refrigerant – Unknown.

#2 – Kold King

- (11) Is gas considered dangerous or not – See appendix on refrigerants.
- (12) Air or water cooled – Air.
The gas is cooled by air, the flywheel having a fan inside it.
- (13) Brine tank used or direct expansion – The liquid used in the tank is not brine, but is Denatured Alcohol and water, this is to eliminate corrosion.
- (14) Retail net price to user – The Kold King Korporation sell the outfit, consisting of a compressor, condenser and evaporator and piping to connect, installed in any refrigerator, for \$150.00.
The electrical connections, they state, will average about \$15.00.
- (15) Guarantee – Unknown.
- (16) Service –

Appendix 49

C. H. LEONARD

Mr. C. H. Leonard is developing a rotary pump machine for the Hoover Company at North Canton, Ohio. They are putting out five machines this year.

- (1) Name of manufacturer – Lipman Refrigerator Car & Mfg. Company.
- (2) Address – Beloit, Wisconsin.
- (3) Resources – This company has just recently reorganized and no financial statement is available. 500 machines in successful operation for 12 consecutive months.
- (4) Models – (1) Model 25 (2) Model 50
Both machines are furnished with low sides to accommodate requirements of refrigerator.
- (5) Size motor – $\frac{1}{4}$ H.P. $\frac{1}{2}$ H.P.
- (6) Cubic contents – Will handle 40 to 100 cubic feet of well insulated space.
- (7) Trays – 3 and 4 8 and 9
- (8) No. cubes per tray 10 10
- (9) Size cubes - 1 $\frac{1}{2}$ " 1 $\frac{1}{2}$ "
- (10) Automatic or non-automatic – Automatic Automatic
- (11) Place where machines is mounted – Can be connected to almost any refrigerator box. Installed conveniently in the basement, beside the box, or on top of it.
- (12) If thermostatic control, give range of temperature – Two degrees above or below predetermined point.
- (13) Usual temperature of ice box - 45° recommended, but can Arrange for any desired temperature.
- (14) Refrigerant used – Ammonia.
- (15) How often resupplied – Ordinarily about four to six ounces per year.
- (16) Cost of new refrigerant – About forty cents per pound.
- (17) Is gas considered dangerous or not - (Text illegible) machine water jacketed and safe-guarded by safety devices.
- (18) Air or water cooled – water cooled.

#2 – Lipman

	(1)	(2)
(19) Cu. Ft. water per day -	6.4 cu. Ft.	12.03 cu. Ft.
(20) Compressor – Reciprocating.		
(21) Brine tank used or direct expansion – Direct expansion with special “hold-over” provision.		
(22) Retail net price to user -	\$400.00	\$500.00
<p>The complete installation of this Model 25 machine sells for \$400.00 f.o.b. Utica, N.Y., although the Electric Refrigeration Company, Inc., will make all installation and pay the traveling expenses of the men to Schenectady.</p>		
(23) Percent discounts to central stations – 40 percent discount to distributors.		
<p>15% discount to dealers.</p>		
(24) Does price include:		
Refrigerator -	No	No
Brine tank -	No tank but includes sharp freezer coil assembly with ice trays.	
Installation -	No	No
(25) Average hours operated per day -	6	6
(26) Estimated KW-hours per day -	1.65	4.0
(27) Guarantee – One year.		
(28) Service – The Lipman machine runs for years with only minor adjustments. Mechanical troubles are almost unknown.		

MATHIS & Co.

- (1) Name of manufacturer – Mathis & Cie.
- (2) Address – 6, Place St. Pierre Le Jeuns, Strasbourg.
- (3) Resources - ?

Remarks:

Mr. Oettli's letter of May 26, says that they are also manufacturing refrigerating machines on the system "Linde" for industrial purposes. I do not believe that this is of interest from the domestic standpoint.

McCLELLAN

It was rumored in Chicago that the Commonwealth Edison Company were going to put out a machine built by the McClellan Refrigerating Company, but nothing could be secured to substantiate this statement.

Mr. D. L. Boyd states that they hoped to sell the refrigerating machine for \$200.00, including the box.

(editor's note: this machine was placed on the market)

APPENDIX NO. 53

1. MAC LAREN FROZEN AIR SALES CORPORATION.
2. 1762 WOOLWORTH BUILDING, NEW YORK CITY.
3. RESOURCES – UNKNOWN.

On June 27, I called on Mr. L.S. McCormick, the president of the Mac Laren Frozen Air Sales Corporation, and he gave me the following facts concerning his machine. It takes air from the box at approximately 40 degrees Fahrenheit, at atmospheric pressure. This air is compressed to 60 lbs. pressure when the temperature becomes 275 degrees Fahrenheit. The air is then cooled in the condenser, after which it is passed through a steam trap on its way to the expansion motor. After expansion, the air is delivered to the box at minus 60 degrees Fahrenheit, atmospheric pressure. Mr. McCormick stated that this machine delivered 5 cu. Ft. of air per minute. It runs with a ¼ H.P. motor. Mr. McCormick claimed that it would keep either the Arlington asbestone box or the Balsa box at proper temperatures with an average input of 1 KW-hour a day.

The following analysis would seem to indicate that
(Text illegible)
boxes at 40 degrees and at the same time making a few pounds of ice with proper allowances for the cooling of food and the losses due to opening and shutting the door of the refrigerator. On the other hand, this analysis indicates that the steam

trap in its present location would be of no use whatever in preventing moisture from entering the expansion motor, and that probably .153 lbs. of water would be condensed and frozen per hour. If this is blown out of the expansion motor in the form of snow, no harm will be done, but theoretically there would seem to be danger of this freezing up the valves.

This analysis shows that under the very most favorable assumptions of almost impossibly high mechanical efficiencies, of 90 percent respectively for both the compressor and the expansion motor, at least 1/3 H.P. would be required and the average KW-hour input per day would be about 2.2 , which is 120 percent high than Mr. McCormick's statement. I cannot but believe that the mechanical efficiencies of the compressor and expansion motor are much worse than 90 percent, in which case, the KW-hour input would be much greater. The fact that the machine runs with a 1/4 H.P. motor would seem to indicate that due to a low volumetric efficiency, which Mr. McCormick may not have considered, the air output at minus 60 degrees Fahrenheit at atmospheric pressure is very much less than 5 cu. Ft. If the air output is less, then the refrigerating capacity is less.

Mr. McCormick said this machine could be built with 60 lbs. of castings. The machine labor would be \$4.58, and the assembly charge very small, making the factory cost about \$50.00 He expected to be able to sell it for \$150.00 for the machine alone, or \$275.00 for the machine including the box.

Before investing any money in this company,
I should feel that tests should be made to determine the
following points:

- 1- Volumetric and mechanical efficiencies
of the compressor and the expansion
motor.
- 2- Whether on long runs the valves
freeze up.
- 3- Whether there is any danger of oil
vapors being carried into the box.

The machine is very noisy and must be re-designed
for quiet operation. The cost of this redesigned machine
should be thoroughly checked in order to make sure whether
it can actually be manufactured for \$50.00.

First Step

During compression, the equation of the air is of
the form,

$$P_1 V_1^n = P_2 V_2^n \quad (1)$$

The temperature would be related by,

$$T_2/T_1 = [P_2/P_1]^{n-1/n} \quad (2)$$

(Text illegible)

possible to solve the second of those equations for the value
of “n”.

$$T_1 = 459.6 + 40 = 499.6$$

$$T_2 = 459.6 + 275 = 734.6$$

-4-

$$P_1 = 14.7$$

$$P_2 = 14.7 + 60 = 74.7$$

Substituting these values in equation (2).

$$734.6/499.6 = [74.7/14.7]^{(n-1)/n}$$

Therefore, taking the logarithms of both sides,

$$.1675 = .706 \times (n-1)/n$$

Solving, $n = 1.31$

The equation of the air during compression is, therefore,

$$P_1 V_1^{1.31} = P_2 V_2^{1.31} \quad (3)$$

The work done during a polytropic change of state such as given by equation (3) is,

$$1^W_2 = \frac{P_2 V_2 - P_1 V_1}{1 - n}$$

(Pressures are in pounds per square foot).

The volume of a pound of air at 40 degrees Fahrenheit and 14.7 lbs. pressure is,

$$V_1 = 12.6 \text{ cu. Ft.}$$

The volume of a pound of air at 275 degrees Fahrenheit and 74.7 lbs. pressure is,

$$V_2 = 3.65 \text{ cu. Ft.}$$

(Text illegible)

$$1^W_2 = 33,100 \text{ ft. lbs.}$$

If this compression had been adiabatic, "n" would have been 1.4. The fact that "n" was 1.21 means that a certain amount of heat was abstracted from the air by the cylinder

walls. This amount of heat is given by the formula,

$$1^{Q2} - W/J \quad [(K-n)/(K-n)] \quad 1/n \quad (5)$$

Where, K = Exponent of adiabatic compression, 1.4.

J = Joules' equivalent, 778 ft. lbs. per B.t.u.

Substituting, $1^{Q2} = 11.7$ B.t.u.

Second Step

The air is now cooled at a constant pressure of 74.7 lbs. from 275 degrees to about 100 degrees. The specific heat at constant pressure is,

$$C_p = .24$$

Therefore, $2^{Q3} = .24 \times 175 = 42$ B.t.u.

Third Step

The air is now expanded from 100 degrees, 74.7 lbs. to minus 60 degrees, at 14.7 lbs. Again, it is necessary to use equation (2) to determine the value of "n".

$$T_3 = 100 + 460 = 560$$

$$P_3 = 74.7$$

$$T_4 = 460 - 60 = 400$$

$$P_4 = 14.7$$

Substituting these in equation (2),

$$560/400 = [74.7/14.7] (n-1)/n$$

Taking the logarithms of both sides,

$$.1461 = .706 \times (n-1)/n$$

Therefore, $n = 1.26$

Therefore, the equation of the air during expansion is,

$$P_3 V_3^{1.26} = P_4 V_4^{1.26} \quad (6)$$

The volume of a pound of air at 100 degrees and 74.7 lbs. is,

$$V_3 = 2.78 \text{ cu. Ft.}$$

The volume of a pound of air and minus 60 degrees and 14.7 lbs. is,

$$V_4 = 10.1 \text{ cu. Ft.}$$

Substituting this in equation (4),

$$3^W 4 = 41,300 \text{ ft. lbs.}$$

Substituting this in equation (5),

$$3^Q 4 = 14.8 \text{ B.t.u.}$$

It will be shown later in the discussion of humidity that 6.96 B.t.u. are given out in the condensing

and freezing of moisture. Therefore, 7.84 B.t.u. must be absorbed from the cylinder walls.

Fourth Step

The air discharged into the box rises from minus 60 degrees Fahrenheit to 40 degrees Fahrenheit at constant pressure. Therefore,

$$4^{\circ}5 = .24 \times 100 = 24 \text{ B.t.u. per pound.}$$

Summary:

Mr. McCormick said that the compressor delivered 3 cu. Ft. of air at minus 60 degrees Fahrenheit and atmospheric pressure. Each pound has a volume of 10 cu. Ft. under these conditions so that only half a pound of air is delivered per minute. Therefore, the cooling effect of this compressor is 12 B.t.u. per minute, or 720 B.t.u. per hour. A little farther on, in the discussion of changes in humidity, it will be found that about .0051 lbs. of water vapor will be condensed and frozen per pound of air. If this is shot out into the refrigerator box in the form of snow, the melting and vaporization of this moisture will add 3.48 B.t.u. per minute, making a total of 15.48 B.t.u. per minute, or 930 B.t.u. per hour as the cooling effect of this machine.

(Our Fort Wayne type OC-2 machine is capable of 1210 B.t.u. per hour).

The hundred pound box made by the American Balsa Company which Mr. McCormick contemplates using has an ice meltage of .802 lbs. of ice per hour when maintaining a 44 degree Fahrenheit temperature of the food compartment on a 70 degree day.

Mr. McCormick said that this machine was capable of making 2 ½ lbs. of ice in one hour at the same time that it was refrigerating the box. The peak load on the machine when maintaining 40 degrees on a 90 degree day would, therefore, be:

	<u>Lbs. Ice per Hour.</u>
To hold box at 40° on a 90° day	1.54
To make 2 ½ lbs. of ice in one hour	3.35
To cool the food in three hours	<u>1.06</u>
Total * * * * *	5.95

Mr. Mullin of the Arlington Refrigerator Company told me that opening and shutting the door in actual practice increased the ice meltage 27%	<u>1.60</u>
Total * * * * *	7.55

This corresponds to 1090 B.t.u. per hour.

Therefore, Mr. McCormick's machine is theoretically capable of keeping this box cool on a 90 degree day, freezing
(Text illegible)
three hours.

The average consumption of the box would be,

	<u>Lbs. Ice in 24 Hours</u>
To hold box at 40° on 70° day	22.2
To make 2 ½ lbs. of ice in 24 hours	3.15
To cool food once in 24 hours	<u>2.35</u>
Total * * * * *	27.70
27% for opening doors	
Total * * * * *	35.20

This corresponds to 5080 B.t.u. in twenty-four hours. Since the machine when operating has a capacity of 930 B.t.u. per hour, it would only have to operate on the average of 5.45 hours per day.

Power Consumed

In the first step it was shown that 53,100 ft. lbs. energy is required to compress a pound of air from atmospheric pressure and 40 degrees Fahrenheit to 60 lbs. gauge pressure and 275 degrees Fahrenheit. Therefore, to compress one-half pound of air per minute would require,

$$\text{Compression I.H.P.} = \frac{1}{2} [53,100/33,000] = .81$$

Similarly in the third step it was shown that 41,300 ft. lbs. energy can be obtained from the expansion of one pound of air at 100 degrees Fahrenheit and 60 lbs. gauge pressure to atmospheric pressure and minus 60 degrees F.

$$\text{Compression I.H.P.} = .81$$

Therefore,

$$\text{Expansion I.H.P.} = \frac{1}{2} [41,300/33,000] = \underline{.627}$$

$$\text{Not I.H.P} = .183$$

It would be reasonable to assume that the compressor has at least 10 percent friction (in fact, it is likely that the combination of volumetric and mechanical efficiency for the compressor would be less than 50 percent). Assuming that the almost impossible has been accomplished, and that the mechanical efficiency of the compressor is 90 percent, the friction loss is .081 H.P. Similarly, assuming an impossibly high mechanical efficiency of 90 percent for the expansion motor, the friction loss is .0627. Adding these to the net I.H.P. gives a total of .3267 H.P.

Can these assumptions, a 1/3 H.P. motor should be sufficient to drive the compressor.

Assuming a 60 percent efficiency for the motor, the electrical input would be .405 kilowatts. If the machine runs 5.45 hours a day, this would correspond to an average input of 2.2 KW-hours per day.

However it is (Text illegible) friction losses could be so greatly reduced.

Humidity

Let us assume that the humidity in the box is 100 percent. The water vapor pressure at 40 degrees Fahrenheit

would be .1217 and the specific volume of this water vapor would be 2446 cu. Ft. The air pressure would be,

$$14.7 - .1217 = 14.5785$$

The specific volume of the air would be 12.6 cu. Ft. Therefore, for every pound of air there would be,

$$12.6/2446 = .00518 \text{ lbs. of steam.}$$

After compressing to 275 degrees and 60 lbs. gauge pressure, the specific volume of the air would be 3.65 cu. Ft. The vapor pressure of saturated steam at 275 degrees is 45.39 lbs., and the specific volume is 9.309 cu. Ft. If the air were saturated, there would be $3.65/9.309 = .404$ lbs. of steam per pound of air. But, since there is only .00518 lbs. of steam, the water vapor pressure must be

$$45.39 \times (.00518 \times 10^{-3})/.404 = .58$$

The saturation temperature corresponding to .58 lbs. pressure is 87.25 degrees. Therefore, at 275 degrees this steam must be super-heated 187.75 degrees.

The thermal potential of super-heated steam

At 275 (Text illegible)

the thermal potential of saturated steam at 40 degrees Fahrenheit is only 1075.7 B.t.u. Therefore, for every pound of steam compressed, 91.3 B.t.u. would be absorbed. Since there

are only .00518 lbs. of steam per pound of air, only .486 B.t.u. would be absorbed per pound of air.

When this combination of air and super-heated steam at 60 lbs. gauge pressure is cooled from 275 degrees to 100 degrees, the humidity increases. The water vapor pressure at 100 degrees is .9461 and the specific volume of the steam is 350.8 cu. Ft. The specific volume of air at 60 lbs. gauge pressure and 100 degrees Fahrenheit is 2.78 cu. Ft. Therefore, if the humidity were 100 percent, $2.78/350.8 = .00795$ lbs. of water vapor would be required per pound of air. Since only .00518 lbs. of water vapor are available per pound of air, the humidity must be approximately 65 percent.

IF THE HUMIDITY IS 65 PERCENT, THE STEAM TRAP WOULD BE UNABLE TO REMOVE ANY MOISTURE FROM THE AIR ALTHOUGH IT MIGHT FURNISH A PURPOSE IN REMOVING SOME OF THE OIL.

When this air with a humidity of 65 percent is expanded from 100 degrees and 60 lbs. gauge pressure down to minus 60 degrees and atmospheric pressure, most of this water vapor is condensed.

I have been unable to find any tables for
(Text illegible)
degrees Fahrenheit and atmospheric pressure, the specific volume of air is 11.6 cu. Ft. The water vapor pressure is .0184 lbs. per square inch and the specific volume of the

water vapor is 14,800 cu. Ft. The weight of water vapor per pound of air would, therefore, be .0000785. But, before expansion the air contained .00518 lbs. Therefore, at least .0051015 lbs. of water vapor must be condensed per pound of air circulated. The latent heat of vaporization is approximately 1225 B.t.u. Therefore, in condensing this water vapor, 6.23 B.t.u. will be absorbed.

Also, in freezing this condensed water vapor into snow or ice, about .73 B.t.u. will be absorbed. This makes a total of 6.96 B.t.u. per pound of air circulated.

Half a pound of air is circulated a minute. Therefore, approximately .00255 lbs. of water vapor are condensed and frozen per minute. This corresponds to about .153 lbs. of water per hour. If this is blown out into the ice box in the form of finely divided snow, the latent heat of fusion and the latent heat of vaporization will be of assistance in cooling the box, as this snow melts and vaporizes.

On the other hand, from book I have read on the subject of compressed air refrigeration, I would be inclined to feel that this .153 lbs. of water condensed and frozen per hour would have a tendency to freeze up the valves of the compressor.

Condenser

As far as I can remember, the condenser consisted of five lengths of 2" pipe, each about $1 \frac{3}{4}$ ft. long.

The area of this pipe would be 4.6 sq. ft.

However, there were cast on the pipe $\frac{1}{4}$ " fins, spaced about $\frac{1}{4}$ " apart. The area of one turn of this fin, taking into account both sides would be about 3.14 sq. in. If they are spaced every quarter of an inch, there will be forty-eight per foot, or 422 turns altogether. This corresponds to an area of about 9.2 sq. ft. Therefore, the total area of the pipe, including the fins, may be approximately 13.8 sq. ft. In the second step of the preceding calculation, it was shown that 42 B.t.u. must be dissipated in the condenser per pound of air. Since $\frac{1}{2}$ lbs. of air is circulated per minute, 21 B.t.u. per minute must be dissipated. This corresponds to 90 B.t.u. per square foot, per hour. When dissipating 90 B.t.u. per square foot, per hour, I believe this condenser would rise about 30 degrees. I, therefore, assumed on a 70 degree day that the air could be cooled to 100 degrees.

MOTORFRIGERATOR

- (1) Name of manufacturer – Motorfrigerator Company
- (2) Address – Lansdale, Pa.
- (3) Resources – This Company has a paid in capital of \$21,000.00 and a manufacturing capacity of approximately \$175,000.00.
- (4) Dimensions:
Weight - ?
Outside dimensions – 52” high, 27” wide, 20” deep.
- (5) Size motor – ½ H.P. motor.
- (6) Ice making – Apparently this machine does not make ice.
- (7) Automatic or non-automatic – Automatic.
- (8) Place where machine is mounted – Under refrigerator.
- (9) Refrigerant used – Ethyl chloride.
- (10) How often resupplied - ?
- (11) Is gas considered dangerous or not – The advertisement says that ethyl chloride is a harmless fluid, having no objectionable odor.
- (12) Air or water cooled – Air.
- (13) Compressor –
- (14) Brine tank used or direct expansion – Direct expansion.
- (15) Retail net price to user - \$250.00, f.o.b. Lansdale, Pa.
This price includes the completely equipped machine in a well built and well constructed refrigerator, so that the only expense of installing when received is to provide a convenient light socket.
- (16) Percent discount to dealers - ?
It is the purpose of the motorfrigerator company to sell this machine direct to the dealers when will be given exclusive territory a on agreement to purchase a certain number of machines.

#2- Motorfrigerator

- (17) Does price include:
Refrigerator – Yes
Brine tank - - - -
Installation – Yes
- Estimated KW-hours per day – 1 KW-hours
- (18) Guarantee – Against defective materials and workmanship for one year.
- (19) Service – “The Motorfrigerator has been thoroughly tested in practical service, and all parts have been standardized for a production in one size and style only.”

F. W. NIEBLING

- (1) Name of manufacturer – The F. W. Niebling Company
- (2) Address – Norwood, Cincinnati, Ohio.
- (3) Resources – This Company has total assets of \$71,000.00, a surplus of \$40,000.00, and a manufacturing capacity of approximately \$100,000.00.
- (4) Automatic or non-automatic – Automatic.
- (5) Refrigerant used – Ammonia.
- (6) Air or water cooled – Water.
- (7) Remarks:
 - “This company has had thirty-nine years’ experience in making refrigerating machinery.
 - “The first practical home outfit built fifteen years ago is still operating satisfactorily and economically.”

NORWALK

- (1) Name of manufacturer – The Norwalk Iron Works Company.
- (2) Address – South Norwalk, Conn.
- (3) Resources – This Company has a capital and surplus of \$1,000,000.00 and a manufacturing capacity of approximately \$1,500,000.00.
- (4) Size motor – ½ H.P.
- (5) Dimensions – 36” long, 18” wide, 26” high.
- (6) Ice making – A pan of cube compartments filled with water can be placed in the Norwalk coil compartment (the chamber formerly used for ice), and in a short time, the water will be frozen into solid, sanitary cubes of ice.
- (7) Automatic or non-automatic – Completely automatic.
- (8) Place where machine is mounted – in basement.
- (9) Refrigerant used – Ammonia.
- (10) How often resupplied – The ammonia supply of the Norwalk plant is replenished not oftener than once a year and ordinarily at about eighteen month intervals.
- (11) Cost of new refrigerant – The ammonia can be replenished when needed at a cost not exceeding \$5.00.
- (12) Air or water cooled – Water.
- (13) Compressor - ?
- (14) Brine tank used or direct expansion – Brine tank.

The three standard sizes of Norwalk brine tanks and coils are as follows:

	Width	Height	Depth
A	11 ¼”	16”	14 ½”
B	14 ½”	24 3/8”	15 ½”
C	16 ¼”	36”	22 ½”

These sizes meet all standard requirements, but where special dimensions are needed for any reason, the brine tank and coils can be easily adapted to (Text illegible)

#2-Norwalk

- (15) Retail net price to user - \$375.00
- (16) Percent discounts to central stations – Unknown.
- (17) Does price include:
 - Refrigerator - No
 - Brine tank - Yes
 - Installations - Unknown
- (18) Guarantee – Unknown.

Remarks:

While the motor-driven type of machine will, of course, be selected wherever electric current is available, the Norwalk refrigerating plant is also supplied for use with a gas engine. In outlying districts where gas engines are frequently employed for other forms of service, it is a simple matter to utilize much power for the Norwalk machine also.

OTTO

- (1) Name of manufacturer – Hall-Borchert Manufacturing Company.
- (2) Address – 1230 Cedar Avenue, Scranton, Pa.
- (3) Resources – This Company formerly built dress forms. They have a paid in capital of \$10,000.00 and are using as capital a surplus of \$70,000.00. Their manufacturing capacity is approximately \$125,000.00.
- | | | |
|----------------|-----------------------------|-----------------------------|
| (4) Models – | Small | Large |
| (5) Contents - | 1150 sq. in. shelf
Space | 1600 sq. in. shelf
Space |
- (6) Ice making – These machines are capable of making 100 cubes of ice per day.
- | | | |
|----------------------------------|-----------|-----------|
| (7) Automatic or non-automatic – | Automatic | Automatic |
|----------------------------------|-----------|-----------|
- This machine is gas heated.
- (8) Temperature range – The Otto machine in its two cycles a day has a temperature range of from 25° to 50°. When run eight cycles a day, the temperature ranges is from 20° to 40°. When it was shut down once at 35°, it took a day and a half for it to reach a room temperature.
- (9) Dimensions:
- | | | |
|----------------------|--------------|--------------|
| Exterior dimensions- | Height- 63” | Height- 37” |
| | Width- 23 ½” | Width- 36” |
| | Depth- 22” | Depth- 23” |
| Interior dimensions- | Height- 39” | Height- 32” |
| | Width- 18 ½” | Width- 24” |
| | Depth- 12 ½” | Depth- 16 ½” |
- (10) Refrigerant used – Anhydrous ammonia.
This refrigerant contains about 7 ½ lbs. of anhydrous ammonia and 7 ½ lbs. of water.
There is a gradual deterioration in the ammonia gas.
- (11) Compressor – There is none.
- (12) Air or water cooled – Water.

#2- Otto

- (13) Cu. Ft. of water per day – 300 gallons.
- (14) Retail net price to user - \$390.00.
- (15) Average hours operated per day – This machine operates twice in twenty-four hours. The two cycles consist of one hour generating and the rest expanding.
- (16) Estimated KW-hours per day – The electricity used is negligible, as the electric current consumed is only for operating the automatic clock.
- (17) Service – The Hall-Borchert Company have had machines in operation for several years, and anyone can see machines in operation either at the Scranton Electric Company or the Scranton Gas and Water Company show rooms at any time.

Once in six months it is necessary to draw water out of the evaporator. In these cases, it would be necessary for a service man to take along an electric vacuum pump to pump out the system.

This machine, which was tested by the Western Electric Company, carried over a certain amount of water vapor which froze in the expansion coils, and it was necessary to melt this and drain it out every once in a while.

During this test, they tried to blow this machine up by turning on the gas and turning off the water, but a maximum pressure of 300 lbs. was reached and nothing happened.

APPENDIX #57-A

OTTO

Mr. Stuart Otto and Mr. L. H. Conklin came up to see me at the request of Mr. Beran of the New York office, to discuss the Otto refrigerating machine.

They showed me a report which Ford, Bacon and Davis has made on this machine at a cost of \$15,000.00.

The machine which they are planning to put on the market is a water and ammonia absorption machine, covered by patent #1,470,638. It has the following advantages.

As shown in the above patent, when the heat is turned on, the liquid mixture of ammonia and water is forced out of the lower compartment into the upper compartment where it boils. The vapors go up past some cooling coils where the water vapor is condensed out. The ammonia vapor goes on into a double pipe, water cooled condenser which consists of 12 ft. of double pipe. From the condenser, the ammonia vapor goes into an expansion system similar to that shown in the pictures of the Mannesmann machine.

The heating period is about 1 ¼ hours and is controlled by a time clock. When the heat is shut off, the cooling water is switched from the condenser to a coil in the generator, then turning the generator into an absorber. The contraction of the gases in the lower half of the generator allows the liquid to return to the lower half and this covers up the pipe

(2)

through which the vapors go from the expansion system. This is all described in the patent. The advantage is that the vapors from the expansion side of the system then have to bubble up through the liquid and this gives very good absorption and prevents the pressures from equalizing too suddenly. In most other domestic absorption machines, there is a mechanical contrivance to make the returning vapors bubble through the liquid, and Mr. Otto's patent obviates this difficulty.

Their small size machine holds 4 ½ lbs. of ammonia, and their large size machines holds 8 ½ lbs. of ammonia. The expansion system consists of 60 ft. of seamless steel tubing which costs them 8 ½ cents a foot. The whole machine is made out of welded sheet iron and there is twenty hours labor on the machine (nine hours labor for welding).

The Easy Washing Machine Company of Syracuse have bid on the machine a factory cost of \$50.00, complete. They expect to buy boxes in lots of five hundred from Wicander & Company, 50 Broad Street, New York City. These boxes will have a total inside capacity of 7 ½ cu. Ft., with 6 cu. Ft. food storage capacity. The boxes are insulated with 2" of cork and have a galvanized iron, #20 gauge lining covered with baked enamel. For \$10.00 additional, the galvanized lining can be covered with porcelain. For \$2.50 additional, the insulation can be increased from 2" to 3". This makes a total factory cost of the complete machine and box of about \$100.00. Ford, Bacon, and Davis says this machine can be marketed with profit for a selling price of between \$300.00 and \$350.00, complete.

(3)

The machine takes about 315 gallons of water a day, running three cycles each of 1 ¼ hours. It consumes 26.1 cu. Ft. of gas per cycle, the gas containing 500 B.t.u. per cubic foot. This is sufficient to keep the temperature in the top of the food compartment below 60° on a 76° day.

Tests on their electric model show that the machine can produce a refrigerating capacity equivalent to 45 lbs. of ice per day, with 3 ¾ KW-hours. This is a performance of about .58 wathours per B.t.u., which is about what I estimated to be the best which could be obtained with an absorption machine. Mr. Otto hopes to improve on this figure.

Mr. Otto believes that 78.3 cu. Ft. of gas would be required to produce the same refrigerating effect. The comparison of 78.3 cu. Ft. of gas against 3 ¾ KW-hours would soon to indicate that two-thirds of the heat in the gas is lost.

If the cooling water leaves the machine at 90°, the maximum pressure in the machine is about 160 lbs. In accordance with the specifications of the Underwriters, they have arranged a blowout disc which, when it ruptures, will first shut off the gas and then open the ammonia system to a sewer connection. The gas will be shut off when the pressure reaches 300 lbs. and the machine will be discharged into the sewer when the pressure reaches 446 lbs. The bulging of the disc shuts off the gas and the machine does not discharge until the disc has punctured. They showed no tests on the machine with the heating unit left on and the cooling water shut off, which indicated that the pressure would never rise about 500 lbs., so that in their estimation

(4)

the rupturing disc safety feature is absolutely unnecessary, and is only included on account of the Fire Underwriters.

Another advantage of this machine is that it is arranged so that any water which accumulates in the bottom of the expansion coils will be sucked back each cycle at the beginning of the evaporating period.

The water will be shifted from the condenser to the absorber by a thermostat device, so that when the heat is turned on the generator the water will flow through the condenser, and when the heat is turned off, the water will flow through the absorber coils.

As mentioned earlier, they intend to control this machine by means of a clock, probably a Warren clock. But, if the customer prefers, they can put a thermostat on the generator which will shut off the power when the temperature has risen to a certain point, and another thermostat in the refrigerator which will turn on the power when the refrigerator temperature has risen to a certain point.

They expect to buy 100 watt heating units from the General Electric Company. I mentioned that this would make a larger maximum demand than the ordinary compression domestic refrigerating machine, but they feel that, since their machine is controlled by a clock, it can be arranged to do this heating during the off-peak periods and that, therefore, the Power Company will not object. Further, their load will be a unity power factor load, whereas the small motors running the compression machines have very bad power factor.

(5)

My chief objection to this machine is that it is water cooled and, of course, this is a commercial question which is open to discussion. Mr. Otto seemed to be able to answer satisfactorily my other previous objections which were:

(a) Danger of Blowing Up: Tests show that there is no danger of blowing up, even if the heat is left turned on and the water is turned off and all safety contrivances are inoperative.

(b) Water Getting Into the Evaporator: The machine includes a pre-cooler which prevents most of the water from getting into the evaporator and is arranged so that any water that does get into the evaporator is returned to the absorber each cycle. Mr. Otto has applied for a patent on this feature and, although he explained to me, does not want it described at present.

(c) Large Power Consumption: By means of the pre-cooler, the power consumption has been improved to approximately the best which could theoretically be expected. The power consumption from test is apparently .58 watthours per B.t.u. Our old water cooled type OC-2 machine had a power consumption of .29 watthours per B.t.u., and we are undecided at present as to whether our now air cooled OC-2 machine takes .323 or .4 watthours per B.t.u. It would look as though this absorption machine only took from 40 to 80% more power than our type OC-2 form "H" machine.

(d) Cannot Be Made Air Cooled: Mr. Otto be-

(6)

believes that he can modify the machine for air cooling, although he agrees that it will be very inefficient in hot weather. Mr. Otto and Mr. Conklin claim that water cooling will not be a disadvantage when these machines are built into large apartment houses. They feel that the water which is run through the machines can be drained into a sunken tank in the basement and used to supply the apartment house with water. If each family had one of these machines taking 315 gallons a day, this would increase the water consumption in the apartment house about 60 gallons a day per person. It is my understanding that the entire water consumption of New York City is at the rate of about 200 gallons per person. Therefore, the water which ran through the cooling coils of the refrigerating machine could probably be used profitably for other purposes in the apartment house.

Another of my objections to water cooling was that the cold water pipe would condense moisture and make dampness between the floors and walls, where water bugs would collect. They answered that, for putting in large apartment houses, the pipes all go up through a ventilated shaft where the moisture would do no harm and would probably be evaporated by the ventilating air.

I guess there is no doubt but that there is a limited market for these water cooled machines at a price of between \$300.00 and \$350.00. It would also look as though Mr. Otto has overcome most of the theoretical difficulties with the absorption machine. Any difficulties which they will have will probably be detail mechanical difficulties.

(7)

Mr. Otto gave me some information on the Keith machine and the Keyes machine, which I have included in separate memoranda for attachment to Appendix #44 and Appendix #46.

ARStevenson, Jr-DW

February 16, 1924.

- (1) Name of manufacturer – Radiant Manufacturing Company.
- (2) Address – Sandusky, Ohio.
- (3) Resources – This Company has a manufacturing capacity of about \$50,000.00. They also have farm lighting sets.

Appendix 59 RAPIDE

- (1) Name of manufacturer – “Omnium Frigorifious”
- (2) Address – 35, Boulevard de Strasbourg, Paris.
- (3) Resources - ?
- (4) Only one model.
- (5) Size motor – 1/6 H.P.
- (6) It is an ice making rather than a refrigerating machine.
- (7) Dimensions:
Weight - ?
Exterior dimensions - ?
- (8) Ice making – Will freeze one carafe of water in one minute, or 2.2 lbs. of ice in fifteen minutes.
- (9) Place where machine is mounted – Anywhere.
- (10) Automatic or non-automatic – Non-automatic.
- (11) Refrigerant used – Sulphuric acid and water.
- (12) Is there a stuffing box – Yes.
- (13) How often resupplied - ?
- (14) Safety shut-off – None mentioned, but this machine is a vacuum machine and, therefore, should not blow up.
- (15) Air or water cooled – Apparently no running water.
- (16) Compressor – Reciprocating, single cylinder.
- (17) No brine tank
- (18) Retail net price to user – Unknown.
- (19) Percent discounts to dealers – Unknown.
- (20) Guarantee – Unknown.

#2 – Rapide

Remarks:

This machine is advertised to make ice in one minute in a carafe of water. It is driven either by hand or with a 1/8 H.P. motor. It employs commercial sulphuric acid. These sulphuric acid machines are described in detail on pages 47 through 51 of, "The Mechanical Production of Cold", by Ewing. Apparently the machine was invented in 1810 by Professor Leslie. This particular Rapide machine is manufactured in Paris. It can be seen in the picture that the machine has considerable glassware in it and there might be danger of breakage, allowing the sulphuric acid to get out.

- (1) Name of manufacturer – Refrigo Corporation.
- (2) Address – Milwaukee, Wisconsin.
- (3) Resources – Paid in capital, \$212,000.00.
- (4) Size motor – ¼ H.P.
- (5) Dimensions:
Maximum weight – 150 lbs.
Exterior dimensions – 11” wide x 19” long x 18” high.
- (6) Trays – 3.
- (7) No. of cubes per tray – 27.
- (8) Ice making – Ample daily supply of pure ice cubes for table use.
- (9) Automatic or non-automatic – Automatic.
- (10) Place where machine is mounted – This machine can be placed on top of the ice box, at its side, or in the basement.
- (11) Refrigerant used – Ammonia.
- (12) How often resupplied – Because of the leak-proof character of Refrigo, the original charge of ammonia will remain intact for a period of many years.
- (13) Is gas considered dangerous or not – Yes (See appendix on refrigerants.)
- (14) Compressor – Special; silent, viatical piston type; all moving parts automatically lubricated; hermetically and automatically sealed to avoid gas and oil leaks.
- (15) Brine tank used or direct expansion – Brine tank.
- (16) Safety shut-off - (Text illegible) device that automatically stops machine in case of excess pressure.
- (17) Retail net price to user - \$365.00.
- (18) Percent discounts to dealers – 30 to 40% in quantities.

#2 – Refrigo

- (19) Guarantee – It is sold under a positive guarantee to give satisfaction.

Remarks:

The following is quoted from the bulletin put out by the Refrigo Corporation:

NO LEAKS

“One of the most serious objections heretofore to the household use of a refrigerating machine was the escape of fumes through the driving mechanism of the compressor and the constant leakage of lubricating oil through the stuffing box.

“These objections—common to all other types of refrigerating machines—are now for the first time entirely overcome. Our engineers, after the expenditure of much time and money, have solved this problem by the invention of an ingenious and clever device known as an automatic sealer and lubricator for refrigerating compressors.

“Heretofore as the pressure in the compressor increased, the leakage of gas and oil increased proportionally. This new device, however, is so constructed that the greater the pressure in the compressor the tighter and more leak-proof the automatic sealer becomes.

“This feature—which represents one of the most important and far-reaching improvements made in recent years in household refrigeration—is thoroughly protected by a broad patent issued by the United States patent office April 6th, 1920. All infringements will be vigorously prosecuted.”

“The Refrigo Corporation makes one size only according to our information, which sells for \$260.00 installed in Milwaukee and outside of Milwaukee \$360.00, plus installation.

(D. L. Boyd.)

- (1) Name of manufacturer – Dr. Rumpler.
- (2) Address – Germany
- (3) Resources – Unknown.
- (4) Models – Apparently there is only one model.
- (5) Ice making – If desired, ice trays may be inserted to produce cubes of clear ice.
- (6) Automatic or non-automatic – Non-automatic; see (13)
- (7) Place where machine is mounted – The Rumpler machine is preferably mounted on top of a well insulated household or store refrigerator, a thick sheet of cork-board being used as a base-plate.
- (8) Usual temperature of ice box – The temperature may be controlled as desired.
- (9) Refrigerant used – Aqua- ammonia.
- (10) How often resupplied – The solution of water and ammonia within the pressure tight machine may be used indefinitely.
- (11) Cost of new refrigerant – Unknown.
- (12) Is gas considered dangerous or not – See appendix on refrigerants.
- (13) Lubricant – The article on this machine says that no lubricant is used.
- (14) Air or water cooled – Water,
- (15) Brine tank used or direct expansion – Direct expansion.

“A direct expansion evaporator hangs down into the refrigerator, occupying the space ordinarily reserved for the center partition. Instead of the usual cubical tank seen in American equipments, which simply takes the place of an equivalent block of ice, a more effective and stronger construction is obtained by Rumpler by means of a grid of straight, vertical, seamless, drawn steel tubes with a horizontal liquid feed header at bottom and a large horizontal suction gas header at top, under the base plates. The tubes offer a large cooling surface, take up very little space, and

#2 – Rumpler

are more efficient for heat absorption than a brine-cooled flat tank surface.”

- (16) Retail net price to user – Unknown.
- (17) Does price include –
Refrigerator - No
Brine tank - ---
Installation - -
The machine is shipped fully charged, ready for water and wire connection, which is a simple matter.
- (18) Average hours operated per day –
One movement with a lever turns on the electric heat for a period of one and a half to two hours, a second movement by hand stops the heat and turns on the thin stream of cooling water. The effective refrigerating period lasts at less twenty-two hours per day. The next day the performances is repeated.
- (19) Guarantee – Unknown.
- (20) Service – There is said to be no appreciable wear and tear, the water tubing within the generator being of a composition metal which is acid resisting.
- (21) Noise – There is no moving machinery and, therefore, no noise or vibration.

Appendix 62 SANITARY

- (1) Name of manufacture – Frankenberg Refrigerating Machinery Company (Successor to Sanitary Refrigerating Machinery Company.)
- (2) Address – 245 Jackson Street, Milwaukee, Wisconsin.
- (3) Resources - ?

Mr. T. I. Jones in his paper, “Household Electric Refrigeration”, which was published in October, 1922, says that there are twelve Sanitary Refrigerating machines which have been in successful operation for at least twelve consecutive months.

- (4) Models - (1) Contemplated (2) At present (3) Contemplated
- (5) Size motor - $\frac{1}{4}$ H.P.
- (6) Cubic contents - 9.6 cu. Ft.
- (7) Trays - 2
- (8) No. cubes per tray - 21
- (9) Size cubes - $1\frac{5}{16}$ " dia, x $1\frac{1}{2}$ " high
- (10) Automatic or non-automatic – Automatic.
- (11) Place where machine in mounted – Under refrigerator
- (12) If thermostatic control, give range of temperature - 5° F.
- (13) Usual temperature of ice box – Average 39° to 44° F.
- (14) Refrigerant used – SO^2
- (15) How often resupplied – Permanent charge.
- (16) Cost of new refrigerant - 75ϕ .
- (17) Is gas considered dangerous or not – Not as used in this machine,
- (18) Is there a stuffing box – Yes.
- (19) Air or water cooled – Water.
- (20) Cu. Ft. water per day – 5 cu. Ft.
- (21) Compressor – Reciprocating.

#2 - - Sanitary

- (22) Brine tank used or direct expansion – Direct expansion.
- (23) Retail net price to user – About \$550.00.
- (24) Percent discounts to central stations – to be determined a little later.
- (25) Does price include:
 - Refrigerator - Yes
 - Brine tank - Yes
 - Installation - No
- (26) Average hours operated per day – 8 hours
- (27) Estimated KW-hours per day – 1.8 KW-hours
- (28) Guarantee – Complete.
- (29) Service – Some time ago, the Western Electric Company bought a Sanitary refrigerating machine. This machine had Bakelite pinions and one of them swelled. Sometimes it was too tight to start. SO² leaked to the outside air. They had trouble with corrosion.

It took two men three days to recharge the machine with SO². They felt it was necessary to wash everything with gasoline before recharging. They also felt it was necessary to heat the whole system while pumping. (I asked Mr. V. R. Greene about this the next day and he said that It was not at all necessary to wash it with gasoline or to Heat the system.) They had no real trouble with the Bakelite gears outside of the time that one of them swelled.

The type RSA motor was noisy.

Remarks:

Water supply for condenser is also automatically controlled and guards against any undue high gas pressure. Water consumption based upon temperatures of water 69°F. and room temperature 75°F.

Late information shows that the Frankenberg Refrigerating Machinery Company, formerly the Sanitary Refrigerating Machinery Company of Milwaukee, are making an ice machine for household use of capacity of 250 lbs., of ice melting per day. The price of this machine is \$575.00 f.o.b. Milwaukee complete. They also state that they will have a machine ready August 15th which will be a complete sulphur dioxide unit of 250 lbs. ice melting capacity complete and ready to run which can be put in any box in two hours, and can be put over or under box or in the basement. This unit is to be sent out fully charged at a cost of \$300.00 f.o.b. Milwaukee.

D. L. Boyd.

- (1) Name of manufacturer – Hercules Corporation.
A recent report indicates that the National Electric Products Corporation, Chicago, is merely distributing and for the time being the manufacturing is done by the Hercules Corporation.
- (2) Address – Evansville, Indiana.
- (3) Resources – The production of this Company in May, 1923, was seven to eight machines a day. Mr. Dennedy, who was formerly on the engineering staff of the Kelvinator Corporation, says that they are handling their machines through the Public Utility Companies, and that all of the companies in the Hodenpyle Syndicate are going to sell their machines. This Hodenpyle Syndicate controls a large number of public utilities in Illinois, Indiana, Michigan and Iowa. The Public Service Companies will sell and service machines.
- (4) Development – Unknown.
- (5) Model – 12 SerV-el.
- (6) Dimensions -
- | | Height | Width | Depth |
|------------------|---------|-------|-------|
| Overall | 74" | 41" | 25 ½" |
| Food Compartment | 30 3/8" | 35" | 16" |
| Cooling Chamber | 13 ¼" | 35" | 17" |
| Machine Section | 18" | 37" | 19" |
- (7) Size motor – ¼ H.P.
- (8) Trays – 8.
- (9) No. cubes per tray – 12.
- (10) Size cubes – 1 1/8 x 1 ½ x 1 ¾".
- (11) Ice making – A total of 288 cubes or approximately 27 lbs. of ice can easily be made in twenty-four hours.
- (12) Automatic or non-automatic – Automatic.
There is no thermostat, but the motor is started and stopped by the pressure switch in the suction line.
- (13) Place where machine is mounted – It is mounted in the lower compartment of a special refrigerator which they build or can

#2 – Servel.

be used in existing refrigerators, and installed remote from the refrigerator.

- (14) Refrigerant used – Methyl chloride.
- (15) Is there a stuffing box – Yes.
The stuffing box is of special construction, and is really labyrinth bearing made up of a number of spring steel discs, with some bronze spacers between them.
- (16) How often resupplied – The National Electric Products Corporation says that the refrigerant should last for years, but is easily replaced if necessary.
- (17) Cost of new refrigerant – Unknown.
- (18) Is gas considered dangerous or not – See appendix on refrigerants.
- (19) Air or water cooled – Air.
The air cooling is furnished by a fan, which is mounted on the idler pulley.
- (20) Compressor – Two cylinder, single acting.
- (21) Brine tank used or direct expansion – Placed in the cooling chamber of the refrigerator is a tank of substantial construction containing a solution of alcohol and water, which absolutely prevents any corrosion that may follow in the use of calcium chloride or a brine solution.
- (22) Retail net price to user - \$395.00.
- (23) Percent discounts to dealer – 15%.
- (24) Average hours operated per day – This machine runs one-sixth of the time.
- (25) Estimated KW-hours per day – 2 KW-hours.
- (26) Description of insulation – The refrigerator which they build is insulated with two inches of sheet cork, with a vitreous enamel steel lining, and steel exterior.
- (27) Guarantee – Unknown.
- (28) Service – Mr. H. E. Crane says that it is easy to see the Kelvinator influence in the design of this machine, but his impression is that is not so well built a machine as the Kelvinator.

Appendix 64 C. K. TRIPP'S MACHINE

* * * * *

- (1) Name of manufacturer – Mr. C. K. Tripp.
- (2) Address – Lynn, Mass.
- (3) Resources – Mr. Tripp has built a couple of refrigerating machines and has orders for ten more.
- (4) Size motor – ¼ H.P. RSA motor, - 250 watts.
- (5) Automatic or non-automatic – Automatic.
- (6) Usual temperature of ice box – Mr. Tripp has a sylphon thermostat with mercury contacts which is operated from the temperature of the brine tank. With this outfit, he succeeded in keeping a pine-board box with nothing but an air space between at 32 degrees.
- (7) Refrigerant used – Sulphur Dioxide
- (8) Is there a stuffing box – Yes,

The novelty of Mr. Tripp's scheme is his method of packing between the low pressure chamber containing sulphur dioxide and the atmosphere. Mr. Tripp has an oil chamber in the lower part of the sulphur dioxide chamber and opposite this is an oil chamber, the upper surface of which is exposed to atmosphere. Between these two chambers is a wall and a packing box through which a rock shaft is passed. This shaft is made to rock by means of an ingenious mechanism which Mr. Tripp has device which transmits the circular motion of the motor (which is placed above the oil level) through the oil so as to rock the shaft mentioned. This shaft passes into the oil at the bottom of the sulphur dioxide chamber and in this oil is a walking beam carrying two connecting rods which operate two pistons, thus actuating a two cylinder compressor which could be of any usual type. There is a flange on the sulphur dioxide side of the rock shaft which is pressed up against a babbit face by means of a spring, thus helping to make the joint between sulphur dioxide and atmosphere. If ever a high pressure comes in the sulphur dioxide chamber, this pressure forces the flange against the face all the harder and effectively prevents any leak.

- He has an oil (Text illegible) the stuffing box.
- (9) Is gas considered dangerous or not – See appendix on refrigerants.

#2-C. E. Tripp's Machine

- (10) Air or water cooled – Air.
- (11) Compressor – Reciprocating two cylinder, single acting.
- (12) Brine tank used or direct expansion – Brine tank.
Mr. Tripp feels that the brine tank is necessary because small motors are inefficient and he feels there is more efficiency in running a large motor part of the time.
- (13) Retail net price to user - \$125.00.
Mr. Tripp feels that his machine can be built in quantities for a factory cost of about \$60.00.
- (14) Average hours operated per day – The motor ran one hour on and one hour off.
- (15) Guarantee – Unknown.
- (16) Service – Mr. Tripp found that it was necessary to pean castings of his cylinders in order to keep them from leaking.

UNIVERSAL ICE MACHINE CO.

- (1) Name of manufacturer – Universal Ice Machine Company.
- (2) Address – 6915 Fort Street, East Detroit, Michigan.
- (3) Resources – This company states that they have had test machines in operating for two or three years and while heretofore they have been making machines one at a time, they have their first twenty-five coming through this month and have a plant and facilities for doubling each month until they meet sales required.
- (4) Refrigerant used – Ammonia.
- (5) Is gas considered dangerous or not – See appendix on refrigerants.
- (6) Air or water cooled – Water.
- (7) Compressor – It has a single cylinder, single acting, 250 RPM Compressor, a proximately 2” by 3”.
- (8) Retail net price to user - \$ 350.00
- (9) Percent discounts to dealers – They state that they intend to establish sales and service agents in exclusive territory.
- (10) Guarantee – Unknown.
- (11) Remarks:
The machine might be good for butcher shops, but does not look very promising as a domestic outfit.

- (1) Name of manufacturer – Utility Compressor Company.
- (2) Address – Adrian, Michigan.
- (3) Resources – There is outstanding at the present time \$300,000.00 common stock, per value \$10.00. The proceeds from this stock have been used in the development of the outfit. Approximately \$50,000.00 of this common stock remains in the treasury unsold. They are now offering \$250,000.00 accumulative preferred at per value \$10.00 per share. One share of no per value common is given as a bonus with each share of preferred. The preferred draws 8% interest payable semi-annually, on the first day of July and the first day of January of each year. Not less than 20% of the net earnings shall be set aside as a sinking fund each year for paying interest on preferred, and to begin retiring preferred each year after the fifth year at \$11.00 per share until 1939, when it is all retirable. The preferred interest must be paid before dividends can be paid on the common or no per common. In case of liquidation, the preferred stockholder must be paid in full with all accumulated interest before common or no par can participate. Preferred does not vote unless interest is defaulted for one year. It then votes until interest arrears have been paid. The common and no par common votes and participates equally in all the earnings, assets and dividends after preferred interest has been paid.

Mr. H. E. Crane, of the Fort Wayne Office, understands that at present the company is simply trying to sell such machines as they have in stock, and are servicing all machines sold. No further manufacturing is to be done until they can refinance.

Mr. A. W. Henshaw says that their authorized now capital is \$600,000.00, but they are understood to be heavily in debt.

- (4) Models - (1) (2) (3)

They make one size mechanical unit which is interchangeable. They make three boxes with different finish only, otherwise exactly alike. Natural wood finish, white enamel finish, white porcelain finish. 69 1/2" high. 37 5/8" wide, 22 5/8" inches deep.

- (4) Size motor – 1/4 h.p.
The motor, which is a Holzer-Cabot 1/4 h.p:

#2 – Utility

1725 RPM, 60 cycle, single phase motor, with shading coils, is mounted in the gas chamber. The Holzer-Cabot company furnishes the rotor and stator only. The stators are furnished wound in the white without treatment. They are then given one dip and one bake of bakelite varnish. They claim to have had no trouble with this treatment. If this statement is true I am satisfied, from our experience, that it is because they had not had a sufficient number of machines developed. (H. E. Crane - - Fort Wayne)

- (6) Cubic contents – 9.2 cu. Ft
- (7) Trays – With each outfit, 12 Pyrex glass, sanitary receptacles, round, 1 ¾ in. diameter x 1 ¼ in. deep, sides slightly tapered.
- (8) No. cubes per tray –
- (9) Automatic or non-automatic – Automatic.
- (10) If thermostatic control, give range of temperature - 5° F.
- (11) Usual temperature of ice box – Can be set anywhere – we advise 50°, 45° low.
- (12) Place where machine is mounted – In top of refrigerator.
- (13) Refrigerant used – SO₂
The machine was originally designed for the use of ethyl chloride with glycerine as a lubricant, but recently they have changed to sulphur dioxide.
- (14) How often resupplied – Never.
- (15) Is gas considered dangerous or not – Not.
- (16) Is there a stuffing box – No.
- (17) Air or water cooled – Air.
- (18) Cu. Ft. water per day – None.
- (19) Compressor – Reciprocating two cylinder, 2 in. bore, 1 ¼ in. stroke.
- (20) Brine tank used or direct expansion – Direct expansion.
- (21) Retail net price to user - \$400.00 \$425.00 \$500.00

This is according to the finish of the box.

See number 4.

#3 – Utility

- (22) Does price include:
Refrigerator - Yes-complete
Brine tank - No brine tank used
Installation - No installation except convenient opening.
- (23) Percent discounts to central stations – 45%.
- (24) Average hours operated per day – with a room temperature of 70 degrees, this machine operates about 6 hours.
- (25) Estimated KW-hours per day – room temperature of 70 degrees, 2.1 KW-hours.
- (26) Guarantee – One year.
- (27) Description of insulation – The refrigerator is one built especially for this outfit, and is insulated with two inches of cork board.
- (28) Service – The following is copied from the bulletin put out by the Utility Compressor Company:
“There is no charging with chemicals or mechanical work of any kind to be done in the home. Delivery is made in two places; first, the mechanical unit; second, one of the refrigerators, the upper portion of which is arranged to accept the unit. Two of our men simply lift and insert the unit into place, connect the cord to the socket; and everything is ready for use. It takes about ten or fifteen minutes to make the installation. Every unit is exactly alike and interchangeable. The same unit fits into any one of the refrigerator bodies.
“our service stations can remove the mechanical unit and replace with another in fifteen minutes, therefore no household need be deprived of its refrigeration nor to have mechanics working in the home making repairs.”

GENERAL ELECTRIC COMPANY
GENERAL OFFICE-SCHENECTADY, N. Y.
CENTRAL STATION DEPARTMENT
1 River Road, SCHENECTADY, N. Y.

August 28, 1924

Household Utilities Corp.,
16 Hendrie Ave.,
Detroit, Mich.

Gentlemen:

Kindly furnish me with prices, specifications and
other data covering your Electric Household Refrigerator.
This information is for my own personal use.

Yours very truly,

F. E. Dunham

(ed note: hand written in script: 'Returned')

Information from Mr. T.
I. Jones' paper on "Household
Electric Refrigeration", published
in October, 1922.

Appendix 67

FRED. W. WOLF

- (1) Name of manufacturer – Fred W. Wolf Company.
- (2) Address –
- (3) Models - (1) (2)
Install on any unit built type of box in
independent unit.
- (4) Size motor – ¼ H.P. – 250 watts.
- (5) Cubic contents – Equal to the melting of ten pounds of ice
per hour.
- (6) Trays – Compartments 3-7 each for two trays.
- (7) No. cubes per tray – each 16- 2 x 2 in. cubes, or 10 lbs.
Chunks.
- (8) Size cubes –
- (9) Automatic or non-automatic – Both.
- (10) If thermostatic control, give range of temperature –
½ degree in food compartments.
- (11) Usual temperature of ice box – 32 to 34 degrees.
- (12) Refrigerant used – Wolf refrigerant.
- (13) How often resupplied – Never.
- (14) Cost of new refrigerant – None.
- (15) Is gas considered dangerous or not – Absolutely safe.
- (16) Air or water cooled – Air cooled, of course.
- (17) Cu. Ft. water per day – None. None.
- (18) Compressor - Reciprocating Reciprocating
- (19) Brine tank used or direct expansion – Direct expansion.
- (20) Retail net price - \$250.00 \$350.00

#2 – Fred. W. Wolf

(1)

(2)

- (21) Percent discounts to central stations – Yes – based on quantity.
- (22) Does price include:
- | | | |
|--------------|----------|------|
| Refrigerator | No | Yes |
| Brine tank | None | None |
| Installation | Separate | None |
- (23) Average hours operated per day – Variable according to box;
2 hrs., 40 minutes, average summer day.
- (24) Estimated KW-hours per day. –
- (25) Guarantee – Replacement.

#3 – Fred. W. Wolf

The following information on the above refrigerating machines was taken from a memorandum made up by Mr. J. G. DeRemer, of the Savage Arms Corporation, on June 29, 1923. Apparently this machine has been redesigned since the time that Mr. T. I. Jones' paper was published.

- (1) Name of manufacturer – Fred W. Wolf Company.
- (2) Address – Wilmington, Delaware.
- (3) Resources – Mr. W. S. Taylor, who is interested in the Fred W. Wolf Company, is now active at Williamsport in financing to start manufacture and distribution.

The machine has been passed upon and approved by Mr. Allen Woolford, Manager, General Electric Company, Baltimore.

- (4) Development –
- (5) Refrigerant used – Ethyl chloride, with some additional chemical.
- (6) How often resupplied – Unknown.
- (7) Air or water cooled – Air.
- (8) Retail net price - \$200.00, including installation.
- (9) Average hours operated per day – 4 to 6 hours.
- (10) Lubricant – Glycerine.
- (11) Guarantee – Unknown.

Appendix 68

WILLIAMS ELECTRICAL REFRIGERATOR – and – SIMPLEX

These two companies are apparently operated by the same man and so far can be seen make exactly the same type of machine, in spite of the fact that there were two separate capitalizations.

- (1) Name of manufacturer – Simplex Refrigerating Corporation.
Address – 40 Flatbrush Avenue, Extension, Brooklyn, N. Y.
- (2) Name of manufacturer – The Electrical Refrigerating Co., Inc.
Address – Woolworth Building, New York City.
- (3) Resources – Simplex Refrigerating Company: Except for the statement that they are not now doing much business, this company refused to give any financial information since 1915, when they gave their assets as \$371,000., including patents at \$268,000.

Description of Simplex:

- | | | | |
|-----|-------------------------------------|--|---------------|
| (4) | Models - | (1) | (2) |
| (5) | Size motor - | 1/3 H.P. | |
| | | 1/4 H.P. is amply large, however the larger frame is employed to insure against possibility of motor troubles. | |
| (6) | Outside dimensions of refrigerator: | 44" x 25" x 60" 48" x 25" x 60" | |
| | | Machine located on top of refrigerator adds eleven inches to height. | |
| (7) | Cubic contents - | | |
| | - - Net storage | 7 1/2 cu. Ft. | 8 1/2 cu. Ft. |
| (8) | Trays | 8 | 9 |
| (9) | No. cubes per tray | 12 | 12 |

#2- Williams.

	(1)	(2)
(10) Size cubes -	2"	2"
(11) Auto. or non-auto.	Automatic	Automatic
(12) If thermostatic control, give range of temp.	2°F.	2°F.
(13) Usual temp. of ice box	42°F.	42°F.
(14) Refrigerant used -	Ethyl chloride	Ethyl chloride
(15) How often resupplied-	Lasts indefinitely	
(16) Cost of new refrigerant -	\$2.25	\$2.25
(17) Is gas considered dangerous or not –	See appendix on refrigerants.	
(18) Air or water cooled -	Air	Air
(19) Compressor -	Rotary	Rotary
(20) Brine tank used or direct expansion –	Brine tank.	
(21) Retail net price -	\$550.00	\$650.00
(22) Percent discounts to central stations - .	None at present	None at present
(23) Does price include:		
Refrigerator	Yes	Yes
Brine tank	Yes	Yes
Installation	No	No
(24) Avg. hours oper- ated per day	8	9-10
(25) Est. KW-hr. per day	2 ½	2 ¾ - 3
(26) Guarantee	3 years	3 years
(27) How many automatic machines have you now in use that have been in successful operation for at least twelve consecutive months – 12.		

The above information was taken from Mr. T. I. Jones' paper, "Household Electric Refrigeration", presented at the forty-first convention of the Association of Edison Illuminating Companies held at the Greenbrier, White Sulphur Springs, West Virginia, October, 1922.

#3 – Williams.

On May 23, 1923, Mr. Stevenson visited Mr. E. T. Williams, of the Simplex Refrigerating Corporation, Sperry Building, Manhattan Bridge Plaza, Brooklyn, N.Y., telephone 5408 Main. He is designing a new refrigerating machine which will have 7 ½ cu. Ft. food capacity and will sell complete for \$350.00. He has a vane type rotary compressor with a ground and lapped steel joint for a stuffing box. He uses ethyl chloride. The lubricant is glycerine with powdered graphite. Some glycerine oozes out through his lapped steel joint, and where it reaches the air causes corrosion.

He is working on a new arrangement where the motor will drive a set of permanent magnets arranged in the form of a sphere. There will be a diaphragm 1/20,000 inch thick in the form of a spherical surface and inside of this will be a twenty pole laminated rotor. Personally, Mr. Stevenson thinks this diaphragm will heat in the same way that the diaphragm of the Autofrigor machine heats.

Mr. Williams has had twenty machines out for two years and has had to replace his stuffing box every year on account of the corrosion, due to the glycerine. He has also had some trouble with cracking of pipe joints.

The rotary vane compressor is made with a clearance of ½ thousandth of an inch. He says he can build the rotor of this compressor for \$15.00. The vanes are held out both by pressure and centrifugal force.

Mr. Williams has spend about \$250,000.00 so far, and when he completes his development next year, would be very glad to turn it over to someone if a satisfactory financial arrangement could be reached.

REPORT
OF
REFRIGERATING MACHINE DEVELOPMENT
AT
FORT WAYNE WORKS

EARLY EXPERIMENTS

In 1911 the General Electric Company undertook the manufacture, for the Audiffren Refrigerating Machine Company, of A-S machines in four sizes: two ton, one ton, one-half ton, and one-fifth ton.

Through our direct connection with the manufacture of these machines, and indirect connection with their commercial exploitation, we were impressed with the desirability of having a smaller unit, suitable for domestic use, of 175 to 200 pound capacity. That is, one which will produce refrigeration equivalent to the melting of 175 to 200 pounds of ice per twenty-four hours. Naturally we first considered the development of a smaller Audiffren machine. An investigation of this problem, however, convinced us that it was not desirable, for several reasons:

1st: This type of construction, entailing the use of open brine and water tanks in which the machine revolves, and the cooling by circulation of brine, does not lend itself to domestic installation on account of the space required, moisture and dirt, inefficiency of outfit in small sizes, and expense of installation and operation.

2nd: The labor cost of construction of a 200 pound machine would be about the same as the 400 pound size, and we would save only a small amount of material.

It was then decided to investigate the many small machines that were being exploited or under development, hoping to find something suitable for the purpose which we could acquire. We purchased and tested several outfits, and inspected many. All had faults or shortcomings as gauged by the standards set up as a result of our six or seven years experience with the Audiffren machine and our study of the domestic and refrigerating problem.

It was then decided we would try to develop a machine which would embody our ideas of the necessary qualifications of a domestic refrigerating machine.

There was a wide spread feeling that a refrigerating machine for domestic use should be built to sell to the ultimate user at \$100 to \$150, and at this price the market would be so large that they could be manufactured on a Ford basis.

The Audiffren machine is hermetically sealed and has no packed glands. In this respect it has been generally conceded superior to any other refrigerating machine. It was, therefore, with reluctance and some misgiving that we considered a design in which the power would be applied through a stuffing box. However, the seemingly unsurmountable

difficulties of building a motor that would withstand the atmosphere of gas and oil, and function properly without attention for years; of getting the current into the motor through conductors with insulation that would be gas and oil tight and still keep the cost within the limits set; together with the fact that all the small refrigerating machines on the market or under development were of the stuffing box type, prompted us to attempt a design in which a stuffing box was employed.

In the Spring of 1917 we made drawings and a working model of an OC-2, Form B machine, using one vertical doubt-acting oscillating cylinder, actuated by an eccentric on a horizontal shaft, one end of which was supported by a blind bearing, the other end passing through a stuffing box in the case and carrying a fly-wheel pulley for belt drive.

(See Plates No. 1, 2 & 3.) Ed note: plates too dark to photocopy however the original GE photos are #'s 142039, 142038, 142062 and are in the GE photo collection at the Schenectady Museum.

The cylinder was submerged in oil, and the compressed gas was carried by a pipe to two closed sheet metal pans arranged with suitable baffles, and connected to an enclosed sump, in which was a float type expansion valve, the condensing pans and float valve being submerged in cooling water flowing through a cast-iron condensing chamber. From the expansion valve the condensed gas was piped into a tank of brine in the ice compartment of the refrigerator. From the evaporator a pipe conducted the expanded gas back to the suction side of the compressor.

Cast iron base carried the compressor, condenser, and belted motor.

The control equipment consisted of the following:

A water valve operated by direct pressure in a sylphon bellows connected to the compressor.

A gas thermostat consisting of a sylphon to which was attached a tube partially filled with liquid SO-2, and a contact lever. The change in pressure, due to boiling and condensing of the gas, actuated the sylphon bellows, which moved the contact lever between two contact points.

A single coil contactor, CR-2820-1018.

Fuse block and fuses, and a tumbler switch.

The tests on this working model showed it to have a good refrigerating capacity, and the outfit looked promising enough to warrant the building of some additional machines, which could be tried out in actual domestic service. Seven (7) machines were built, three being installed in homes of employees of the company in Fort Wayne, two in the Works Cafeteria, and the balance in the Testing Room.

One of these outfits operated successfully for a year and three months; one for eleven months, and the balance failed in from two weeks to six months. Trouble soon developed in the sheet metal pans used for condensing and evaporating pipe for condenser and evaporator. The principal source of trouble, however, was the stuffing box.

4.

The experience gained through the operation of these seven machines, coupled with our observations of the troubles other manufacturers were having with stuffing boxes, has convinced us that a successful domestic refrigerating machine must be one in which the machine and motive power are enclosed in a gas tight case. We realized that this type of construction meant an increase in the cost, with a corresponding reduction in the extent of the market.

In the various attempt at developing a domestic refrigerating machine, practically every type of compressor has been tried. In selecting the oscillating cylinder type of reciprocating compressor, we are not making an experiment. Abbe Audiffren, in the development of the A-S machine, used at different stages most of the types of compressors that are being tried by various manufacturers at the present time, only to discard all of them for the oscillating cylinder type, which has been used in the Audiffren machine for twenty-five years.

In September 1919 an appropriation was approved to make drawings, patterns, tools and build one model of a 400-lb. domestic refrigerating machine with totally included motor.

This size was selected, as it would permit of the use of standard Audiffren #2 cylinders, snifter spring valves piston, piston rods and straps, eccentric, and float type expansion valve.

The Schenectady Research Laboratory developed some metal glass leads, giving us a gas and oil tight means of getting the current through the enclosed case.

The use of a motor sealed up in an atmosphere of SO-2 gas and oil was the only radial departure from common practice or our practice in the A-S machine.

Various types of motors were considered for the purpose and, after weighing the advantages and disadvantages possessed by each, it was decided that a split phase motor, having a wire wound stator and a squirrel cage rotor, offered the fewest complications. The restrictions of the N.E.L.A. in regard to starting current allowable did not give us a very wide leeway on starting torque, but it seemed sufficient.

The construction adopted is shown by Plate #4. Ed note: plate too dark to photocopy however the original GE photo is # 142303 and is in the GE photo collection at the Schenectady Museum.

The tests made on this machine were very encouraging, and three additional machines of this size were built, tested, and put in service. The designation of this size is Type OC-3, Form E.

TYPE OC-2, FORM E DEVELOPMENT

Satisfied that this type of construction was practical, we then designed a 200 # machine, type OC-2, Form E, suitable for domestic, use, and built five (5) models. (See Plate #4.)

In the first machine of this type we used motors having the standard insulation treatment. These motors functioned properly, but after several months of operation

we opened one of the machines for examination, and found the compound had flaked off. Then followed a long list of experiments with various treatments, from which it was found that a motor having the least amount of treating compound necessary to hold wires in position gives the minimum amount of trouble. During all of these experiments, no motor failed, due to lack of insulation. The troubles were all due to compound coming off the wire and interfering with the operation of the compressor by gumming the bearings or clogging the expansion valve.

In the use of the split phase motor, means must be provided to cut in and out the starting winding.

In this application, the motor being sealed up in the gas tight case, it is very important that we employ the minimum number of moving parts and keep out of the case any parts that are subject to wear or liable to get out of order. Our Experimental Laboratory developed an external device providing a means for cutting in and out the starting winding and also protecting the motor against excessive current. (See Plate #5.) Ed note: plate too dark to photocopy however the original GE photo is # 142202 and is in the GE photo collection at the Schenectady Museum.

For the automatic control of temperature, we used the Type SL gas thermostat. (See plate #6, Fig. 1) (Ed note: GE photo# 142306) which in conjunction with the starting relay designed by the text illegible and stopping of the motor.

For the automatic control of the cooling water we designed a water control valve to operate as a function of the temperature of the water in the water jacket of the machine. (See Fig. 1, Plate #7) Ed note: GE photo# 142304

This consists of a sylphon in a cast brass case located outside the casing. From the bottom of the sylphon a copper tube, sealed at the free end, extends into the water liquid, preferably Ethyl-choride, which due to changes in the temperature of the water in the water jacket caused the sylphon to expand or contract, and this motion was transmitted to one end of the valve stem of an ordinary Lunkenheimer whistle valve by means of a pin, causing the valve to open when the cooling water reached a predetermined temperature; the valve was closed by the pressure of a phosphor bronze helical spring on the other end of the valve stem.

The top bearing of the motor shaft is lubricated by oil forced through the hollow shaft by a centrifugal pump located at the lower end of the shaft which is submerged in the oil in the compressor case. On the motor shaft is mounted a machine steel pinion in mesh with a fabrooil gear on the eccentric shaft through which the speed is reduced from 1725 RPM to 493 RPM.

Two (illegible text) oscillating cylinders actuated by piston rods, eccentric straps, and eccentric are submerged in oil.

The condensing chamber is located below the compressor chamber with which it is in communication by means of two stand pipes opening near the top of the compressor chamber well above the oil level. In the condensing chamber is a coil of copper pipe through which the cooling water passes from the hollow base. This pipe is extended through the compression chamber to the water jacketing space surrounding the motor housing.

In the bottom of the condensing chamber is a sump for the collection of the condensed gas, and in this sump is located the float type expansion valve. The machine is mounted on an insulated lid which closes the opening in the top of the cooling compartment of the refrigerator. From the lower side of this lid is suspended the lid of the brine tank, which supports the evaporator, consisting of two coils of copper tubing connected to the bottom of a brass cylinder closed at both ends which constitutes the oil separator. From the expansion valve a small copper tube conducts the liquid SO-2 into the top of the oil separator. From the middle of the oil separator, a larger copper tube passes through the top of the oil separator and extends up to the top of the condensing chamber where it enters the illegible text to the suction ports of the cylinders.

The brine tank enclosing the expansion coils is fastened by screws to its lid. At the bottom of the

brine tank is an insulated freezing compartment containing two pans in which about four pounds of ice can be frozen for table use.

This was the condition of the development at the end of 1920. The five OC-2 machines of this model had been put through numerous factory tests with satisfactory results, but the real test for a device of this character is operation in actual service under the conditions obtaining in different households in different sections.

In January, 1921, it was decided to make this trial, and that for convincing results about twenty-five (25) installations should be made.

It was originally intended to sell a few machines but just about the time we were ready a U.S. Patent, No. 1362757, was issued to Douglas Henry Stokes of Cremorne, near Sydney, Australia, and our Patent Dept. withdrew their approval of our design. Later patent approval was again given on our design. As we had our machines ready, and summer was approaching, we decided to place the machines in service, on a consignment basis, with our own people at Schenectady and Fort Wayne, so that we might have practical experience from these machines under varying conditions of operation.

The difficulty of finding a number of
Illegible text out in their refrigerators
for an experiment of this kind, coupled with the fact that the majority of ice cooled refrigerators are not suitably

insulated for mechanical refrigeration, made it necessary to purchase refrigerators for the purpose. Accordingly, after an investigation of many of the leading makes of refrigerators, and consulting with the manufacturers regarding the construction and size desirable, we ordered from the Jewett Refrigerator Company of Buffalo, a design embodying the arrangement and features we felt best suited for this purpose. (See Plate #23.) (Ed. Note GE photo# 142219) The outfits were built, and early in the Spring of 1921 installations were made. Mr. E. G. Waters arranged for the placing of ten (10) outfits at Schenectady, and Mr. Hunting assigned the balance.

All of these outfits are charged to the individuals on consignment, Mr. H. J. Riffel, Industrial Control Engr. Dept., was assigned to install and service the machines at Schenectady. The balance of the machines were taken care of by the Refrigerating Dept. of Fort Wayne.

With each machine at Schenectady and Fort Wayne was installed a special M-2 Demand Motor, arranged to record the number and duration of the operating and idle periods. Charts were changed once each week, at which time readings were taken of temperatures in the refrigerator, and daily records of air temperatures at Schenectady and Fort Wayne

Illegible text

All of these outfits replaced the existing means of refrigeration, and it was, therefore, important that continuity of service be maintained, and observations

and changes be made with the least possible annoyance to the users.

During this trial period, whenever a machine failed or developed a fault in any part, it was brought back to the factory, carefully examined, repaired, and the design of the part modified if required.

The changes made in the various parts of the machine, based on our experience, were neither fundamental nor serious and were, as will be seen from the following paragraphs, accessory details which were easily corrected. The fact that some machines are still operating satisfactorily with parts which have proven defective in other machines shows clearly the necessity for having experience from quite a number of machines before deciding on a design for commercial exploitation. As an illustration: The Fabroil gears proved defective, and yet several machines are still operating with such gears. If we had put out but two or three machines we might have been deceived about the Fabroil gears if they had been the few that have so far continued to give service.

MODIFICATIONS

MOTOR: The construction of the motor is the same at this time as when these trial machines were built, the troubles with treating compounds having been encountered and worked out in the first models, and a treatment of one dip and one bake of G. E. #450 Varnish adopted as standard.

METAL GLASS LEADS: The metal glass leads, as developed by the Research Laboratory at Schenectady, consisted of a conductor placed in a glass tube with thick wall and a bore slightly larger than the diameter of the conductor. The glass tube was inserted in steel tubing, the inside diameter of which is slightly greater than the outside diameter of the glass tube. It was then heated in a hydrogen furnace and swaged down, a portion being left the proper diameter on which to cut a 3/8" pipe thread. In the leads furnished for these trial machines the distance between the outer sheath and the conductor was very small, especially at the end inside the machine and considerable trouble was experienced with leads becoming grounded at this point. The leads were then changed, leaving the inside end the same diameter as the threaded portion, which gives sufficient insulation. Since this change we have had no trouble. (See Plate #16) (GE photo # 142299)

GEARS: In the experimental machines we first used spiral metal gears. These were too noisy and the next attempt was a Micarta pinion and cast iron spiral gear. This combination failed, as the Micarta would not stand up in the oil and gas. We next tried a machine steel pinion with a spiral fabroil gear and as this combination was satisfactory so far as noise was concerned, it was used in the trial machines. After a few weeks of operation several of the machines became noisy and (illegible text) the teeth of the gears were stripped, and an investigation of these failures convinced us that fabroil gears would not be satisfactory

for this purpose and a change was made to machine steel, herring bone pinion and Alquist type cast iron herring bone gear, which is the standard at this time.

CYLINDERS, PISTONS, PISTON RODS,

ECCENTRIC STRAPS & ECCENTRIC: In the OC machine we use the same type of oscillating double acting cylinders, pistons, piston rods, eccentric straps and eccentric as has been used in the A-S machines for years, mounting these in a horizontal plane, which is preferable to the vertical plans mounting made necessary by the construction of the A-S machine. Only one change has been made in these parts since the original model. In the A-S cylinder the piston rod passes through a gland in the yoke end head which construction requires very close fitting piston. (See Fig. 1 Plate 12) (GE photo # 142301) We found that when the machine was stopped in certain conditions of temperature we did not have sufficient starting torque in the motor to start it. We then extended the piston rod through the head end of the cylinder giving the piston rod a bearing in both yoke and head end of cylinder. (See Fig. 2, Plate 12) This permits of an easier fit between the piston and the cylinder wall, reduces to a minimum the possibilities of wear at the point where the piston rod passes through the yoke end of cylinder, and keeps the piston in perfect alignment. This change has entirely overcome the tendency to stall the motor and enables it to start the machine under and conditions of temperature with terminal voltage as low as 60 volts.

FLOAT VALVE: The float type expansion used is the A-3 machine was adopted for the OC machines with a slight modification. The shape of the valve seat was changed to minimize the chance of foreign matter lodging in the opening and the plunger rod was provided with a steel pilot to keep the opening clear. These changes have since been standardized for the A-S machines.

EQUALIZING VALVE: In our first machines we made no provision for equalizing the differences in pressure between the condenser and the evaporator when the machine was stopped. The only way these pressures could equalize was by leakage past the valves and considerable times was necessary to accomplish this. The result was that the motor would stall if an attempt was made to start the machine shortly after it was stopped. This as a condition apt to arise due to temporary interruption of the current.

None of the small refrigerating machines on the market have an equalizing device, but we felt such a device was desirable and we developed a centrifugally operated equalizing valve(See Plate # 15) (GE photo # 142308) similar to the equalizing valve used in the A-S machine.

This consists of a means for opening a passage from the condenser to the evaporator just before the machine stops, thereby equalizing the pressures and reducing the starting torque required of the motor. This was incorporated in all of the later machines.

EVAPORATOR BRINE TANK

AND COOLING MEDIUM: The evaporator and brine tank used in these trial machines is shown on Plate #8.

No change has been made or found to be desirable in the evaporator.

The brine tanks were made of sheet copper which was found unsatisfactory, due to the odor produced by the oxidation of the copper. The advantage of the cylindrical shape, as far as ease in cleaning is concerned, is offset by the disadvantage of its having smaller cooling surface than a rectangular tank adaptable for the same size cooling compartment of a refrigerator. The freezing compartment for making table ice was attached to the bottom of the brine tank, but we found the time required for freezing by this method was excessive, due to the fact that the only cooling surface available was the top of the compartment. On account of these objections we made the later brine tanks of sheet steel rectangular in shape, with an opening in the front in which we welded a freezing compartment so that it is surrounded by brine on all sides except the front. The size of the freezing compartment has been increased so that 8 pounds of ice can be frozen, whereas only four pounds could be made in the original compartment. (See Plate #9) (GE photo# 142309) For installations where a larger quantity of ice is required, we are developing an outfit to cool a refrigerator, and at the same time freeze illegible text

The sheet steel tanks were painted, but we have had some trouble with the surface rusting, which we think can be overcome by covering the tank with a vitreous enamel. This we are trying out at the present time. Various cooling mediums have been tried but brine made from common salt (Sodium chloride) seems to be the most satisfactory. Calcium chloride has no advantages over sodium chloride for the temperatures at which we work, and is more expensive, harder to mix, and must be very carefully handled. A glycerine and water solution was tried out but we found that the water would freeze out of solution. Ethylene Glycol and Carbon Tetrachloride were considered, but found to be too expensive. Alcohol is unsuitable because it is too volatile and its odor is objectionable in a refrigerator.

The experience we have had with the machines installed on these special Jewett refrigerators indicates that the brine tanks now in these refrigerators are too small for the best results, but the size of the tank was limited by the size of the cooling compartment in the refrigerator. Experience indicates that for best results a refrigerator should have a cooling compartment the volume of which is 25% to 35% of the total volume of the refrigerator. This is a matter to be taken care of when applying our machines to any given refrigerator.

LUBRICANT: The lubricant used in this machine is a mineral oil developed by the Standard Oil Co. of Indiana, for use in the A-S machine. It is satisfactory in all temperatures

ordinarily encountered in this class of work, but it is not altogether satisfactory for temperatures below 6°F.

Our experience with the A-S machine indicates that an animal or a vegetable oil is not suitable for use in a sulphur dioxide refrigerating machine, because they form a quantity of foam, and tend to form an emulsion which prevents the proper separation of oil and refrigerant and otherwise interferes with the functioning of the machine. The best oil for this work has been found to be a colorless mineral oil. At first, a Russian colorless mineral oil was used in the A-S machines, but after the source of supply of this oil was cut off by the war, a colorless mineral oil, produced in California, was substituted. Great care in exercised to insure that the oil is free from moisture or acid. This is refined by the Standard Oil Co., and is known as #2470 oil. Its physical characteristics are as follows:

Chill Point	6°F
Cold “	4°F
Viscosity at 85°F	422 seconds Saybolt Viscometer
Viscosity at 105°F	230 “

This has been used in all OC machines, and has proven satisfactory.

WATER CONTROL VALVE: The automatic valve for controlling the flow of cooling water through the machine has been the source of considerable trouble. The construction of the design sent out on the trial machines is shown by Fig. 1, Plate #7. (GE photo # 142304) In this the sylphon is located outside the casing.

with the volatile liquid tube extended into the water jacket of the machine. On account of the large part of the pressure imposing element being outside the water jacket, the temperatures of the water at which the valve would open and close, were effected by the temperature of the ambient air.

To overcome this, the design show in Fig. 2, Plate #7 (GE photo # 142304) was used, in which the sylphon with its cast brass case was put inside the water jacket, the base of the sylphon being fixed to the case with the top free to move responsive to pressure of gas on the inside. The action of this design was sluggish and we then changed to the design shown in Fig. 3, Plate #7, in which the sylphon is enclosed in a spun copper case attached to the top of the sylphon: the pressure pin in this design passing into the sylphon and being fastened to the bottom or free end. The volatile liquid was put inside the spun copper case surrounding the sylphon so that pressure were exerted on the outside of the sylphon instead of on the inside as in previous designs. This was an improvement over the previous attempts, but still not satisfactory. The many transfers of heat in a design where the vavle is operated as a function of the cooling water temperature results in a lug in its operation, which permits undesirably high temperature and pressure to build up in the compression chamber. We then changed to the design shown in Fig. 4, Plate #7. In this a smaller double ply sylphon is sealed inside the compression chamber and operated as a function of the pressure in the compression chamber. This has given no trouble and

its action is very satisfactory. With the maximum travel of 1/16" and the maximum pressures to which the sylphon will be subjected, the manufacturers guarantee a life of two to three million strokes, which would make it safe long beyond the life of this machine.

THERMOSTAT: For the automatic temperature control of the OC outfit a design of thermostat as shown in Fig. 1, Plate #6 (GE photo # 142306) was made in which one end of which makes contacts in a relay circuit. A small quantity of sulphur dioxide is placed in the metal tube, the free end of which is then sealed off. When the temperature of the tube is changed, the pressure in the tube and sylphon is changed causing the sylphon to expand or contract and move the lever. The adjustable counterweight provided means for raising or lowering the temperature and the range was adjusted by moving the contact points.

At the time this was used we were attempting to control the temperature, between narrow limits, in the food compartment of the refrigerator. This we found was impractical for the reason that improper loading of the food shelves or obstruction of the air passages often retarded or stopped illegible text the result the machine would run until the brine was frozen up.

We then decided to control the brine temperature and also to lengthen the duration and reduce the number of

running periods of the machine. This requires a wider range than we could get with this design, which already required too much space, so it was changed as shown in Fig. 2, Plate 6, (GE photo # 142306) in which a helical spring was used for a coarse balance of the sylphon, the finer adjustment being accomplished by a counter-weight on a shortened lever.

In both the first and second design some trouble was caused by chattering of contact due to vibration. To overcome this we changed the design to that shown in Fig. 3, Plate #6, in which the lever is extended beyond the contacts and on insulated block fastened to the end. Adjustable pins are provided so that the insulated end of the lever touches the pin and the lever is flexed to make the contact. This counter-weight was omitted and means provided for finer adjustment of tension of helical spring to raise or lower the temperature.

STARTING RELAY: The starting relay used in connection with the thermostat as one designed by the Industrial Control Dept. at Schenectady. The single coil relay, CR-2820-1018, was used on the experimental machines, but did not prove reliable. This was discarded for the double coil type CR-2820-1033-A (See Plate #10) (GE photo # 142302) which was used on the trial machines. We have experienced no trouble from this source.

STARTING AND OVERLOAD DEVICE

FOR SPLIT PHASE MOTOR: This device, developed by the Experimental Laboratory at Fort Wayne, had been used on all

of the OC, Form E machines and has proven satisfactory. The only changes made were the use of a molded base instead of a wooden base as furnished with the first outfits and size of contact points increased. (See Plate #6) (GE photo # 142306)

CONTROL CABINET: For the mounting and protection of the control devices a sheet cabinet was developed. In the first design the back and two sides were made in one piece with the top, bottom, and front in one piece, studs extended from the four corners of the back through the front which was held in place by wing nuts with provision made for scaling wires. The cabinet was mounted at the side of the machine and supported by iron brackets from the base. The metal glass leads from the machine extended into the cabinet through holes in the back. (See Plate #14) (GE photo # 142111)

The cabinet contained the fuse block, tumbler switch, thermostat, starting relay, starting and overload device and wiring. This cabinet was not satisfactory, and it was changed to the design shown in Plate #10 (GE photo # 142302), in which the back and four sides are in one piece, with a removable cover forming the front, which is held in place by two bolts with wing nuts.

The cabinet in the present design is supported by brackets bolted to the flange between the compressor and condenser chambers. The back end is provided with conduit bushings for the currents leads. The front end carries the tumbler switch, overload react button, and a starting button.

The starting button is provided to permit of manually starting the machine at anytime.

PRESSURE OVERLOAD

PROTECTIVE DEVICE: Plate #11 (GE photo # 142305) shows a device for automatically stopping the machine whenever the pressure reaches a predetermined maximum. This consists of a small double ply siphon with plunger, placed in the compression chamber the same as in the water valve, the plunger being arranged to open the motor circuit when predetermined pressure is reached. This device has been tried out in one machine and functions properly, but it will not be incorporated in the machine until something of this kind is required by legislation or competition.

WATER INLET: The water control valve is used to regulate the time at which water is running through the machine, so that water will be used only when needed. In order to control the amount of water supplied to the machine, we employed a globe valve or a needle valve in the supply line, adjusting those valves for the admission of the proper amount of water. It was soon found that these valves were a source of trouble, due to the lime, coals or sediment collecting in the valve and due to the erosion of the valve points and seats. To overcome these troubles we designed a water inlet, as shown in Plate #13, (GE photo # unknown) which consists of a valve body on which is placed a removable strainer and in the outlet and of which is screwed a plug with a small orifice drilled through it. This orifice is made of the proper size to

permit the flow of the right amount of water according to the temperature and pressure of the water supplied. The high velocity of the water through this small orifice insures its being kept free from deposits. Fixed orifice plugs of various sizes are available for the different conditions of water supply. These plugs are interchangeable and easily removed. The strainers can be easily removed and cleaned when necessary without interfering with the operation of the machine.

SYLPHON BELLOWS: A sylphon bellow is used in the thermostat and another one is used in the water control valve. This is a device made by the Fulton Company, Knoxville, Tenn. It consists of a flexible metal bellows as shown in the Plate #17. (GE photo # 142300)

Tests on these devices indicate that the average sylphon can be subjected to over 3,000,000 complete cycles of expansion and contraction without failure, and that the single ply sylphon is satisfactory for use in the thermostat where the travel does not exceed 1/32" and the gas pressure does not exceed 60 pounds per square inch but averages about 30 pounds; while the double ply sylphon is satisfactory for use in the water control valve where the gas pressure does not exceed 65 pounds and the stroke is not more than 1/16".

These devices are widely used in temperature and pressure control work. They (illegible text) to be reliable and to have a long life.

APPLICATION OF MACHINE: Many small refrigerating machines are connected to refrigerators by drilling through the wall

or the top of the refrigerator, making the openings slightly larger in diameter than the diameter of the connecting pipes, which are then run through these openings. A few OC machines were connected up in this way, one of these being shown in plates Nos. 21 and 22, (GE photo #s 142095 and 142094) where the two small pipes run down from the machine, through the back of the refrigerator, into the ice compartment, and into the evaporator. This method of connecting is objectionable in that it makes it necessary for machine and refrigerator to be assembled before machine is charged; and if repairs are necessary, machine must be discharged on the job, or refrigerator must be returned to the factory with the machine.

Another method tried out was that of mounting the machine in a compartment in base of refrigerator, as shown in Plate No. 3, (GE photo # 142062) where a type OC-2, Form B machine is mounted in base of Monroe refrigerator. While this was a somewhat neater and more easily handled outfit, it was open to the same criticisms as the above described outfit. In order to overcome these disadvantages, the machine was mounted on a base which would fit into an opening about 14" x 14" out in the top of the refrigerator; the brine tank, with evaporator, was mounted below this base, as shown in Plate #8. (GE photo # 142307) Connecting pipes and thermostat tube are run through this base, making this a complete unit which can be assembled, charged and tested in the factory, after which it can be shipped out and set in place with base resting in opening in

top of refrigerators. In case repairs are necessary, this unit can be removed from the refrigerator and returned to the factory, and another unit put in its place.

This type of unit can be used in practically any kind of refrigerator, when an opening of the proper size is cut in the top of the refrigerator, and it can also be used on brine tanks, drinking water tanks, etc., by using the base on which the machine is mounted to form a part of the cover of the tank.

This unit construction is decidedly advantageous in manufacturing, shipping, and servicing the outfits, but it has the disadvantage, when applied to a refrigerator, of requiring considerable head room about the refrigerator, and it is further objectionable in that it sometimes causes the noise and vibration from the machine to be amplified because the machine is not fastened down to a solid foundation. Our experience, however, has been that in a majority of installations the noise and vibration are not objectionable.

COMBINATION ICE MAKING &

REFRIGERATING PLATE:

In common with most all manufacturers of domestic machines, we made our first designs and installations by combining the refrigerating machine with the box. We mounted it on top of the box immediately over the ice compartment. The purpose (illegible text) of first cost and a minimum cost of operation, as the refrigerating machine does not have to handle and heat except

that which it extracts from the box, there being now brine or gas lines that are absorbing heat. In many homes, however, this type of installation does not meet the requirements.

The location of the refrigerator may be such that the small amount of noise from the refrigerating machine is objectionable, or a very considerable quantity of ice may be required in addition to the cooling of the refrigerator itself. To meet such conditions we have developed two types of installations illustrated in Plates 19 and 20. (GE drawing #s K-1793000 and K-1793008)

Plate #19 illustrates the type of installation where we mount the refrigerating machine in the basement or some other place a little distance say from the refrigerator, in order to eliminate the noise. In this type of installation two small copper pipes heavily insulated connect the refrigerating machine with the evaporating coils in the brine tank in the ice compartment of the refrigerators. The one line carries the liquid SO-2 to the evaporator and in the other line the expanded gas is carried back to the compressor in the machines. Such an installation as this has been operating very successfully since last July in the residence of Mr. P. S. Hunting at Fort Wayne.

Plate #20 illustrates the type of installation to be used where a considerable quantity of ice is required, more that is made by the small pans in the brine tank, and where it is desirable to locate the machine in the basement or some other place a little remote from the refrigerator itself.

This installation is similar to that illustrated in Plate #19 except that in addition there are two small copper heavily insulated lines connecting the header in the brine tank with a coil in a brine tank in the basement, in which are located the cans of water to be frozen. Such an installation as this has been under test in the factory for several weeks, and while not all the tests on it are completed, it gives every evidence of being entirely satisfactory. The usual type of installation, where a considerable quantity of ice is required, is to mount the refrigerating machine on the top of the brine tank, in which the ice cans are located, and then, by means of a pump, circulate brine from this tank to coils in the ice compartment of the refrigerator. (See Plate #18) (GE photo # 142310) There are some serious objections to this type of installation. First, it costs more to install; second, the brine pump is a device requiring considerable maintenance; third, a most serious, of all, it cost a good deal more to operate because it is necessary to operate the brine pump motor continuously and in 24 hours operation the energy required is almost as much as is required for the intermittent operation of the refrigerating machine which does the cooling. The type of installation shown in Plate #20 (GE drawing # K-1793008) eliminates the brine pump with all its noise, trouble, maintenance expense, illegible text outfit is very little more than that required to cool the refrigerator and to freeze the ice. Our effort in

developing this combination ice making and refrigerating type of installation has been to reduce first cost by eliminating the brine pump, and by having somewhat smaller insulating lines to connect the machine with the box and the freezing tank. We also eliminated what is most important of all, the extra cost of current required to operate the brine pump.

From a technical standpoint, there has been some question as to just how the freezing in the ice making tank is brought about, whether by evaporation of the liquid SO-2 in the coils in the brine tank, or by thermo-syphon circulation of the liquid SO-2 between the coils of the freezing tank and the header in the brine tank in the refrigerator.

Whether the freezing in the ice making tank is brought about by evaporation or a thermo-syphon circulation, or by both, it is not important, since the installation does the work satisfactorily.

When the development appropriation is available for further experiments, we shall investigate in detail just how this type of installation operates, but for the present it is sufficient to say it operates very well, and gives us an efficient and reliable type of installation.

CAPACITY AND EFFICIENCY: The tests on the OC-2 machine show that it has a capacity of 1000 B.T.U. per hour with condensing water temperature of 77°F, (condenser pressure of 48 pounds per square inch) and a brine temperature of 23°F. This is equivalent to the melting of 167 pounds of

ice per twenty-four hours. Under these conditions the machine requires 0.28 watt hours B.T.U. of refrigeration produced. Under the same conditions the #2 A-S machine has a capacity of 1850 B.T.U. per hour. (1.85 times the capacity of an OC-2 machine) Similar tests show that the #2 A-S machine requires 0.32 watt hours per B.T.U. of refrigeration produced. It should be noted that the OC-2 machine requires less than 90% of the power required by a larger unit, which would naturally be expected to be more efficient.

The OC-2 machine operating as above requires about 8 gallons of condensing water per hour, raising the temperature of this water about 30°F.

The thermal efficiency of the outfit is, therefore, About 60%.

October 24, 1923.

APPENDIX #70.

ADDITIONAL INFORMATION

Requested by
Mr. E. W. Rice, Jr.

I. A type OC-2 refrigerating machine was placed in Mr. E. W. Rice's home and put in operation on April 14, 1921. Attached is a history of this installation which has been prepared by Mr. E. C. Givens, from the data in the Fort Wayne files.

A summary of this history is as follows:-

(A) CHANGES.

- (i) Brine tank - 5 changes in design.
- (ii) Thermostat - 1 change in location, another in design.
- (iii) Water valve- 2 design changes.
- (iv) Gears - Omitted entirely in last machine.

There was no interruption to service during the minor changes.

The major changes were made by replacing the machine with up-to-date models. This was done three times:

#10035	changed to	#10041	2 ½ hrs.	interruption
#10041	“	“	#10031	1 hr. “
#10031	“	“	#10015	3 days “

This last change was due to an unexpected failure of the Water valve and there was no spare machine available.

(not legible)

(B) ADJUSTMENTS.

- (i) Thermostat – 8 adjustments, total of 100 hours interruption.
- (ii) Water valve – 7 adjustments, no interruptions, Interruptions due to adjustments, 100 hours.

(C) FAILURES.

- (i) Thermostat – 1 failure.
- (ii) Water valve – 9 failures, 72 hours.
- (iii) Brine tank – 1 failure, 60 hours.
- (iv) Relay – 1 failure, 24 hours.
- (v) Overload – 5 failures, 69 hours.

(D) SUMMARY.

Changes - - - - - 75 ½ hours
 Adjustments- - - - - 100 hours
 Failures - - - - - 231 hours
 Total interruption - - - - - 406 ½ hours

Total time, April 14, 1921 to

Oct. 22, 1923, 921 days or 22,100 hours.

Percent interruption 1.84%

(E) SUMMARY.

	Hours	Total Number of adjustments, changes or failures
Thermostat	100	10
Water valve	150	18
Brine tank	63 ½	6
Relay	24	1
Overload	69	6
Total	406 ½	41

It was quite a difficult job to differentiate the above into the various headings because the line is rather indefinite between adjustments and failures; also, the wrong kind of solution in the brine tank caused the overload relay to trip out, etc.

The above classification, however, shows roughly that about half the total trouble was due to the water valve.

II. It is my understanding that Mr. Rice's machine is an up-to-date, water cooled machine with two exceptions.

(A) One of the test machines at Fort Wayne is equipped with a thermostat where the contact is made by tipping a tube partially filled with mercury. This device has sufficient current carrying capacity so that the auxiliary relay is unnecessary. This change will simplify and cheapen the equipment. It is very likely that it will be adopted.

(B) The really up-to-date machine is air cooled.

III. ENGINEERING COMPARISON.

The most prominent competitors are: The Frigidaire, the Kelvinator, the Servel, Coldak, Odin, Professor Keyes' machine, and the Savage Arms machine.

(A) The following list of advantages and disadvantages of the machine in Mr. Rice's house is given for comparison with competing machines.

a. Advantages

(i) No stuffing box.

- (ii) Motor is inside where no dirt can get into the bearings. The oil never gets dirty and should last indefinitely.
- (iii) No gears.
- (iv) Centrifugal unloader which makes it possible to use an inexpensive split phase motor.
- (v) Iron brine tank with porcelain finish, which is not likely to corrode. The competing machines have all had trouble with corrosion of the brass or copper brine tanks.
- (vi) Special oil which does not thicken too much at low temperatures, nor thin too much at high temperatures. The oil also has a low Specific Gravity, so that it floats on the heavy, liquid SO₂, making a very reliable oil separator.
- (vii) Oscillating cylinder construction with snifter spring discharge valves, which makes a simple and reliable compressor.
- (viii) Water cooling is a disadvantage, but the water control for this machine is simpler than for the Frigidaire. The type OC-2 machine has a permanent regulation for the amount of water. The automatic control only starts and stops the flow. The Frigidaire attempts to automatically adjust the flow of water and this further complication gets out of order frequently
- (ix) The machine is a unit which can be easily removed and replaced by a spare machine, in case of trouble. No pipe connections are ever made or broken in the field and this reduces the danger of getting moisture into the system.
- (x) Water cooling gives slightly higher efficiency.

b. Disadvantages.

- (i) It is water cooled.

- (ii) The thermostat and control relay can probably be improved as suggested in Section II.
 - (iii) If anything goes wrong inside the machine, it has to be returned to the factory or a service shop for repairs. I doubt if this is a disadvantage because if a system containing sulphur-dioxide is opened in the field, there is a good chance of moisture getting in, which would form sulphurous acid.
 - (iv) If the water fails, sometimes the overload relay will not shut the machine down until an excessive pressure has blown all the oil into the expansion coils. It will probably be legally necessary to furnish a fusible plug as a safety valve which, in case of water failure, might blow out, filling the house with sulphur-dioxide.
 - (v) If the machine is installed in a cold room, the water jackets might freeze up in winter.
 - (vi) There is a chance that power companies might object to the split phase motor.
 - (vii) It is impossible to use a direct current motor.
- c. Advantages of new air cooled machine.
- (i) It has all the advantages enumerated above, and eliminates the disadvantages of water cooling.
 - (ii) It is hard to imagine the machine building up an excessive pressure because the air cooling would condense any vapor forced into the high pressure side of the system. There is only a very slight chance that if the low pressure side springs a leak, that air might enter and be compressed into the high pressure side, causing excess pressure.
- d. Disadvantages of new air cooled machine.
- (i) There is a slight chance of excess pressure, as mentioned in the last paragraph.

- (ii) Since the motor is inside the casing, it cannot be used to drive an external fan for air cooling. It would be too expensive to furnish a separate fan motor and, it is therefore necessary to rely on natural circulation.
- (iii) There is a chance that power companies may object to the split phase motor. This is being investigated.
- (iv) It is impossible to use a direct current motor.

(B) FRIGIDAIRE.

a. Advantages as compared with Fort Wayne type OC-2 machine.

- (i) It has several years commercial experience behind it.
- (ii) The motor is outside where it can be repaired if necessary. This also makes it possible to use a commutator motor.
- (iii) Water cooling gives a higher efficiency.

b. Disadvantages.

- (i) It has a stuffing box.
- (ii) The motor is out where dirt and moisture can get into it. This makes it necessary to renew the oil once in a while.
- (iii) It has gears. But they are very good, noiseless, gears. Their chief disadvantages are: extra expense, and complication.
- (iv) It has no unloader and, therefore, an expensive commutator motor is necessary.
- (v) I believe they have a copper brine tank. The electrolytic action with the copper eats out any soldered joints.
- (vi) It is water cooled and has an automatic adjustment of the quantity of water which gets out of order.

- (vii) The machine is not a unit and pipe joints have to be made or broken whenever it is installed in, or removed from, a box.
- (viii) It might freeze up in a cold room.

(C) KELVINATOR.

a. Advantages.

- (i) Several years' commercial experiences behind it.
- (ii) The motor is outside where it can be repaired if necessary. This also makes it possible to use a commutator motor.
- (iii) It is air cooled, which eliminates trouble with water valves, etc.

b. Disadvantages.

- (i) It has a stuffing box.
- (ii) The motor is outside where dirt can get into the bearings and the oil has to be removed.
- (iii) It is belted.
- (iv) There is no unloader so that it is necessary to use an expensive commutator motor.
- (v) It has a copper brine tank which may give trouble, although they claim that with their new joints all previous troubles have been eliminated.
- (vi) It has poppet valves which become noisy, and sometimes pound their way through the valve seats.
- (vii) The machine is not a unit, and pipe connections are necessary during installation.
- (viii) It has a diaphragm operated expansion valve, which we do not believe is so good as the float valve in the Fort Wayne machine.

(D) SERVEL.

a. Advantages.

- (i) The Servel is almost exactly like the Kelvinator with the following exception.

1 – It uses methyl chloride instead of sulphur-dioxide. This is claimed to be an advantage because it is not such a noxious vapor as sulphur-dioxide in case it escapes into the room. However, it is impossible to use oil with methyl chloride; therefore, the lubricant is a mixture of glycerine and graphite.

2 – They mount a fan on the idler pulley, which improves the air circulation.

3 – They have an automatic device which, in case the expansion side of the system runs at too high a pressure, will throttle the suction to the compressor, thus preventing an overload on the motor.

b. Disadvantages.

- (i) It does not have very much commercial experience behind it.

NOTE: Except as otherwise stated, this machine appears to me to have all the advantages and disadvantages of the Kelvinator.

(E) COLDAK.

a. Advantages.

- (i) This has a high speed rotary compressor which is direct connected to the motor, thereby eliminating gears.
- (ii) It is air cooled, and a fan is mounted on the motor shaft.
- (iii) It uses ethyl chloride which runs at low pressure. They have a patent on the addition of a certain amount of alcohol to the system which prevents any moisture in the

ethyl chloride from freezing.

b. Disadvantages.

- (i) It has a stuffing box.
- (ii) They use Mobile "B" oil, in which the ethyl chloride dissolves under certain conditions, spoiling the viscosity so that the oil no longer acts as a seal and consequently the pressures will not build up.
- (iii) It has a rotary compressor which they claim is inexpensive to build. Most of the mechanical engineers whom I have consulted feel that all rotary compressors are bad mechanical propositions, both from the standpoint of manufacture and maintenance.

Except as mentioned above, the Coldak has about the same advantages and disadvantages as the Kelvinator.

(F) ODIN.

a. Advantages.

- (i) It uses air as a refrigerant, against which there is no prejudice.

b. Disadvantages

- (i) It looks expensive to build because there are two cylinders, each containing two pistons operated by cams. Also, the cylinder walls are of a honeycomb construction.
- (ii) Although silent at present, I believe that as the machine wears it will become noisy.
- (iii) The air cycle is inherently very inefficient; although the boxes which are furnished with this machine have double the insulation of almost any other box, the power required to refrigerate it is about

3 or 4 KW-hours a day without ice and 4 or 5 KW-hours a day if ice is made; whereas, the other machines all run with between 1 and 2 ½ KW-hours a day consumption.

(G) PROFESSOR KEYES' MACHINE.

The national Automatic Refrigerating Company is about to exploit an absorption machine made by Professor Keyes. This is not at present a competitor, and I am only including it in this comparison because it is of special interest.

a. Advantages.

- (i) It has a solid absorbant which makes it superior to any other absorption machine, because all other absorption machines absorb the ammonia in water and a certain amount of steam boils off with the ammonia. This steam condenses in the expansion of the ammonia.
- (ii) It is noiseless because there are no moving parts.
- (iii) There are no oil difficulties because there are no moving parts.
- (iv) Perhaps it is inexpensive to build. I do not know how much the solid absorbent costs. The composition of the solid absorbent is a secret.

b. Disadvantages.

- (i) It uses ammonia, against which there is a prejudice.
- (ii) There is a slight chance that it might blow up if two automatic safety features should both fail.
- (iii) It is very inefficient because it takes the electric power which has been produced at a low efficiency from heat, and degenerates

it back into heat. They estimate 3 KW-hours a day, but I believe it will run higher than this in actual services.

(H) SAVAGE ARMS MACHINE.

The Savage Arms machine is not yet on the market, but I am including it in this comparison because it is the only machine which I believe, at present, is perhaps superior to our Fort Wayne air cooled design. For a detailed description of the Savage Arms machine, please refer to Appendix #14, of the report on Domestic Refrigeration, where it is described in detail.

a. Advantages.

- (i) There are no moving parts in the interior and, therefore, no oiling difficulties.
- (ii) It is impossible to build up an excess pressure except in the very unlikely case of the motor running away, because the pressure depends on the speed.
- (iii) Since there is no internal oiling, it is possible to use any refrigerant. They do use ethyl chloride.
- (iv) I believe it will be inexpensive to build.
- (v) It is hard to imagine very many things that could go wrong with it.
- (vi) It has no stuffing box.
- (vii) The windage of the machine furnishes air circulation for the condenser.
- (viii) Very little starting torque is required so that an inexpensive split phase motor can be use.
- (ix) The motor is outside and, therefore, if the Power Companies insist on it a commutator motor can be used, and also a direct current motor can be used in places

where alternating current is not available.

- (x) The method of operation of the compressor is such that there are no losses due to re-expansion in clearance space, or due to slippage of vapor past piston rings. I believe that careful comparative tests would probably show this machine to be more efficient than any of the other types.

b. Disadvantages.

- (i) The motor is outside so that the oil will have to be removed from time to time.
- (ii) They have had a little trouble with the freezing of moisture in the expansion valve, but I feel quite sure this can be overcome by carefully drying the ethyl chloride before charging the machine.
- (iii) The machine is balanced at full speed and normal pressures. It is slightly out of balance when starting or stopping. This has made it necessary to mount it on flexible supports.

IV. COMPARASION OF PRICES.

It is very hard to make a comparison of prices because the Fort Wayne machine has never been put in real production as yet and the other machine are sold in different sizes, some with and some without boxes. It is hard to be sure that the following attempt at a comparison is a fair one.

Fort Wayne, type OC-2 machine, complete with 7 or 9 cu. Ft. box. (This includes an installation cost of \$60.00)	-	-	-	ap.	\$ 500.
Frigidaire, complete with 9 cu. Ft. box. (This does not include installation)	-	-	-		595.
Kelvinator, without box but claimed to be good for 7 to 10 cu. Ft. (This does not include installation)	-	-	-		287.

Servel, complete with 14 cu. Ft. box. (I doubt if this includes installation) -	-		\$ 395.
Coldak, without box or installation -	-	-	295.
Odin, (They do not make a 9 cu. Ft. equip- ment.) There 5 cu. Ft. equipment costs	-	ap.	495.
\$800.00 or \$850.00, depending on whether ice making capacity is required.			

These prices for the Odin include boxes.

Professor Keyes machine. This machine is not on the market yet and, therefore, we have no prices. Professor Keyes believe it can be built for a factory cost of between - - 30. & 40.

However, this does not mean much because methods of figuring factory costs differ so widely in different factories, and so far as I know, Professor Keyes has had no practical manufacturing experiences.

Savage Arms Machine. The Savage Arms Company have quoted us a price of - - - 600.
on an experimental model, complete with box, etc. Undoubtedly, this experimental model cost more than \$600.00. I believe that later they will easily be able to sell a machine, complete with 9 cu. Ft. box, for less than \$500.00

MR. E. W. Rice, Jr., Schenectady.

Type OC-2 Form E Refrigerating Machine #10035.

Shipped March 26, 1921. Put into operation April 14, 1921.

Thermostat spring adjusted to reduce the running time May 1st, May 6th, and May 10th. No interruption to service.

Increased the quantity of cooling water on May 27th, and June 25th. No interruption to service.

Thermostat adjusted for lower refrigerator temperature on July 12th. No interruption to service.

Trouble with water valve on Aug. 5th and Aug. 9th. About eight (8) hours interruption each time. Temperature in the refrigerator not above normal.

Trouble with water valve on Aug. 16th, Aug. 19th, and Aug. 23rd. No interruption to service.

This was one of the first machines sent to Schenectady. It was equipped with the round copper brine tank with small freezing space under the tank, and with the first forms of the thermostat and the water valve. The bulb of the thermostat was placed outside of the brine tank.

It was found that better results could be obtained by placing the bulb of the thermostat in the brine tank. This gave better control of the temperatures, thus decreasing the number of adjustments necessary. Later models were built in this way. It was also found that much of the sparking and chattering of the thermostat could be overcome by extending the lever which carried the contact points and providing it with an insulated block which worked between two adjustable pins, so that when the insulated block touched one of the pins the lever would flex in order to make the contact. The design of the thermostat was changed accordingly.

Several improvements were made in the water control valve as experience indicated that they were desirable. The valve on this machine was equipped with a rubber washer fastened to the stem with shellac. In several instances these washers came loose from the stem and clogged up the valve, thus shutting off the flow of cooling water. This happened on machine #10035 on Aug. 5th and again on Aug. 9th (noted above) and on each of these dates

the valve stem and washer were removed and replaced by another stem and washer of the same design. This last stem did not seat perfectly and the valve did not always close off completely. This was noticed on Aug. 16th, 19th, and 23rd (noted above). In the later design of water vane this washer is threaded into place. The air cooled machine, of course, has no water valve.

It was found that the round brine tanks did not provide sufficient cooling surface and that a square tank with more cooling surface

-2-

could be put into the same size cooling compartment. It was also found that the copper tanks were not satisfactory, due to an odor probably caused by the oxidation of the copper. The next tanks were made of sheet steel. It was also found that the freezing compartments placed under the tanks, with only the top of the freezing compartment exposed to the brine, were very inefficient, and required very long freezing time. To overcome this an opening was cut in the front of the later style square tanks and a freezing compartment welded in, in such a way that the top, bottom, back and two sides of the freezing compartment were exposed to the cold brine.

Machine #10035, although still operative, was removed on Aug. 22nd and replaced by machine #10041, embodying the improvements above described. Machine #10035 was returned to the factory and brought up to date. Service was interrupted for about 2 ½ hours while machines were being changed. Brine temperature not above normal.

Type OC-2 Form E Refrigerating Machine #10041.
Installed Aug. 22nd, 1921.

Much trouble was experienced during the first week or two due to the thermostat not being in proper adjustment when the machine was shipped from the factory. On this account, service was interrupted about 36 hours from Aug. 23rd to 25th, about 40 hours from Aug. 27th to 29th and about 24 hours from Aug. 29th to 30th. This machine was shipped out with the thermostat in this shape because Mr. Orr expected to be in Schenectady and wanted to try adjusting the thermostat when the machine was installed, but due to a change in plans he did not go to Schenectady at that time and there was a misunderstanding whereby Mr. Riffle thought that the thermostat had been adjusted at the factory.

The brine tank of this machine was filled with a solution of glycerine in water. This had been suggested as an improvement over the salt solution and it was being tried out at that time.

It was found that the glycerine would freeze out of solution and that the brine tank could not be maintained at the proper temperature without having the machine operate with extremely lower evaporator temperature. This operating at low temperature caused trouble when the automatic device would close the circuit to start the machine, that is, at the time of starting there would be an overload on the machine which would stall the motor and bring into play the overload device. Service was interrupted in this way for about 3 hours on Sept. 15th and for about 60 hours from Sept. 16th to Sept. 19th.

In spite of the fact that the evaporator was very cold, the brine tank was not cold enough, therefore the ice which had been frozen was often found to be melted before it was removed from the machine. The glycerine solution was abandoned and the brine tank filled with a salt (NaCl) solution on Oct. 3rd, 1921. No interruption to service on this date. A different adjustment of the thermostat was then found to be necessary. This was made without interrupting service.

This machine was equipped with a water valve which was actuated by

-3-

a slyphon bellows which operated as a function of the temperature of the water in the water jacket of the machine. Due to the fact that it required some time for the water in the jacket to warm up there was a considerable time lag between the operation of the machine and the operation of the water valve, so that the machine would run for some little time before the flow of cooling water was started, therefore it would build up a high condenser pressure. Therefore, this type of water valve caused erratic action of the machine. These high pressures caused the machine to use an excessive amount of current and sometimes caused the overload device to stop the machine. The overload tripped on Oct. 21st. Service was interrupted for about 12 hours. The buzzer did not sound because of a loose lead. Service was again interrupted in this way for about 56 hours from Oct. 22nd to Oct. 25th.

The thermostat was adjusted on Nov. 16, 1921. No interruption to service.

On Dec. 20, 1921, the water valve was adjusted so as to make it open sooner after the starting of the machine. No interruption to service.

On March 21, 1922, the water valve was again adjusted. No interruption to service.

April 18th, water valve completely out of service. No interruption to the operation of the machine. The water was allowed to flow continuously through this machine until the machine was replaced on Nov. 21st. The later type of water valve operates as a function of the pressure in the compressor so that there is practically no lag in its operation. This type of valve is much more satisfactory.

April 19th, thunderstorm caused a disturbance on the power lines. The overload device shut down the machine. The overload was not reset until after about 14 hours interruption.

The next trouble encountered was with the overload device which was adjusted to trip on too low a current. This caused interruption to the service for about 47 hours from April 13th to 15th and for about 8 hours on May 2nd. The adjustment of the overload was changed on May 9th. No interruption.

On July 18th the thermostat was found to be leaking. A new thermostat was installed. No interruption to service.

On Aug. 14th the thermostat was adjusted to reduce the temperature in the refrigerator. No interruption.

On Oct. 31st the water pipes were flushed out and the water supply was adjusted. No interruption.

The sheet steel brine tank on this machine had been painted with a special paint adapted to withstand the severe conditions of humidity and temperature. However, these tanks rusted very badly and the next development was a steel tank covered inside and outside with

a vitreous enamel. Due to the condition of this brine tank and to the fact that at this time all machines were being replaced with rebuilt machine, embodying other refinements of design, this machine was replaced on Nov. 21st, 1922 with machine #10031. Service was interrupted for about one hour while the machines were being changed. Machine #10041 was returned to the factory and rebuilt, being brought up to date.

Type OC-2 Form F Refrigerating Machine #10031.

Installed Nov. 21, 1922.

The relay was out of order Dec. 3rd and 4th. Service was interrupted for about 24 hours.

The machine was shut down from Dec. 5th to Dec. 12th to see if it was needed during the winter months.

The water valve was adjusted Dec. 13th. No interruption.

The water valve was cleaned Jan. 30, 1923. No interruption.

The charts on this machine show some long idle periods during the Spring of 1923, apparently for the purpose of defrosting. They do not show any notation of trouble.

The demand motor was taken out of service on May 1, 1923.

The machine failed on May 19th and was replaced by machine #10015. Machine #10031 would not produce any appreciable amount of refrigeration at the time it was removed from this installation, but when it was received in Fort Wayne it had a normal refrigerating capacity. This trouble was due to a defective water valve, the plunger being of an absolute design, it having a short housing for the rubber seat which allowed the seat to come loose from the housing. The valve should have been equipped with a plunger having a longer housing but the old style plunger was put in through an oversight in the factory. The rubber seat coming loose, plugged up the valve and stopped the flow of cooling water, thus causing the machine to build up an excessive pressure in the condenser with the result that the oil, which normally forms a seal around the float valve, was forced through into the evaporator so that the machine would not function any longer. The jarring of the machine during transportation, caused

some of the oil to run down from the compressor case and again seal the float valve so that the machine operating normally when it was received in Fort Wayne. However, after the machine had been running for some time in Fort Wayne, the water valve again caused the same trouble and it was then found that the valve was defective.

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Type OC-2 Form E Refrigerating Machine #10015.

Installed May 19th, 1923.

This was one of the first machines shipped to Schenectady, and it

-6-

put on this installation temporarily and with the understanding that it would be replaced as soon as a machine for this installation was received from Fort Wayne. It was replaced June 14, 1923, by machine #10036.

- - - - -

Type OC-2 Form G Refrigerating Machine #10036.

Installed June 14th.

In operation to date. (Oct. 11, 1923.)

No reports of trouble.

Apopendix 71
MANNESMANN TIEF KUHLSCHRANK
* * * * *

- (1) Name of manufacturer – Mannesmann Industrie and Handelagesellschaft M. B. H.
- (2) Address – Berlin W. 50, Tauentzienstrasse 19A.

This machine is of the absorption type and was invented by Dr. Rumpler. This Company has apparently done quite a business. They furnish a pamphlet with thirty-three references from satisfied users. Their representative for Great Britain, Ireland, Canada, and British India is H. Barash, 30 Mincing Lane, London, E. C. 3.

This machine is very simple, as will be seen from the detailed description of the apparatus and its operation at the end of this appendix. The refrigerator boxes are particularly interesting because they apparently have 5.9” of cork insulation. Due to this very thick insulation, a very small refrigerating machine is able to maintain a temperature of 39° in the box, and make 5 lbs. of ice a day (this 5 lbs. can be frozen in two hours).

The most interesting thing about the machine is that it is very cheap; the smallest size has a net resale price, f.o.b. Hamburg, including export license and export duty of \$82.00. The import duty into this country would probably be 40%. The cost of the refrigerating machine in this country, neglecting ocean freight, would be \$112.00.

The resale price of the box, f.o.b. Hamburg, including export license and export duty, is \$41.00. The

duty on the box would be 33 1/3%. Therefore, the price of the box in New York, neglecting ocean freight, would be about \$55.00. This makes a total price for box and machine of \$167.00. This is the smallest size, and the capacity is only 4 cu. Ft. Assuming a 40% discount, this would be a selling price of around \$280.00 for the machine and box. The Frigidaire 5 cu. Ft. machine and box, Model B-5, sells for \$495.00

This model runs on 2 KW-hours a day and 106 gallons of water a day, while the Frigidaire, Model B-5, takes approximately 75 to 150 gallons of water a day. An absorption machine of this kind is inherently very inefficient, but the power consumption is kept down to a reasonable figure by the 5.9" of insulation.

These prices are very interesting because they are so low, but Mr. Henshaw tells me that they are no lower than he would have expected considering the low cost of labor in Germany. He feels that we should not take the low price of these machines as an indication of superiority in design.

This Company makes these refrigerators in two styles, one for temperate climates and one for tropical climates. The machine is water cooled and in temperate climates they expect the cooling water to be between 50 and 54 degrees, whereas the machine for tropical climates is designed for use with cooling water as warm as 77 degrees Fahrenheit. This indicates a possible disadvantage of the

(Ed. NOTE: page 3: Picture and Diagrams too dark to copy)

machine because in the southern parts of our own country the city water supply runs, in hot weather, as high as 100 degrees.

DESCRIPTION OF CONSTRUCTION AND OPERATION (See Sketch)

A. The Box

Special technical consideration has been given to the construction of the box with a view to obtaining good insulation. It is constructed of double walls, the inner sides of which are covered with insulating paper between which insulating material, high grade cork slab is firmly pressed in. The inner space is covered according to requirements with zinc, glass, or tiles, and contains detachable shelves, as shown in the picture. There is a small waster pipe in the bottom of the box to drain off melted frost. All five types shown in the foregoing table are supposed to have 150 mms. of insulation. This is equivalent to about 5.9". The pamphlets claim that the machine is capable of maintaining a temperature of 39 degrees Fahrenheit inside the box.

The foregoing table shows that the ratings of the machines are very small; therefore, the insulation must be pretty good, if a temperature of 39 degrees is maintained. All this, taken together with the low price given in the foregoing table would seem to indicate that the boxes are remarkably inexpensive, considering their supposed quality.

B. Refrigerating Apparatus

The refrigerating apparatus is fixed in and on the box and is easily removable. The following are the principle parts of the apparatus:

1 – Boiler (No. 1)

The boiler (absorber) consists of a small tank, inside of which is fixed a pipe (No. 2), through which cooling water passes during the later period of absorption. In the case of electrical heating, two tubes pass through the bottom of the boiler and form containers for the heating elements (No. 3), afterwards referred to as heaters.

2 – Automatic Disconnecter (No. 4)

This serves the purpose of cutting off the current at the end of the heating period and turning the cooling water through the absorber. It consists of the following three parts:

- a) A membrane (No. 5)
- b) A water diverter (No. 8)
- c) A service lever (No. 6)

It can be seen in the sketch that there is inserted into the boiler a tube (No. 5a). This is filled with water and is connected to the membrane (No. 5). When the boiler is heated to the proper temperature, the water in this pipe boils and causes a pressure on the membrane which trips the service lever (No. 6), allowing the weight

to turn it around the hinge (No. 6b). The movement of this lever produces the following effects:

- a) The current is cut off at the contact (No. 7).
- b) The water flowing from the cooling water container (No. 17) through the pipe (No. 17a) becomes diverted from funnel 17b into funnel 17c, from which it flows through the cooling pipes (No. 2) in the absorber.

3 – Water Separator (No. 9)

this is a small tank placed in the cooling water container (No. 17) and connected with the boiler (No. 1) by a pipe (No. 1a). Any steam which goes over with the ammonia vapor from the boiler is condensed out and settles in the form of water in the bottom of this water separator. When the apparatus is reversed, this water is blown back into the boiler.

4 – Condenser (No. 10)

This consists of a coiled pipe situated in the water container (No. 17).

5 – Evaporator (No. 11)

This consists of an upper manifold and a lower manifold connected by vertical tubes. The liquid ammonia evaporates in this, this causing the refrigerating, (No. 12) is an ice cell in the form of a detachable metal cup, where a small block of pure ice is formed (I understand that 5 lbs. of ice can be made in two hours).

6 – Ammonia Threeway Valve (No. 14)

This is fixed in the connection between the

water separator (No. 9) and the condenser (No. 10), and the valve has also a direct connection with the lower manifold of the evaporator (No. 11).

C. Operation of the Plant

The boiler (No. 1) will be heated when the service lever (No. 6) is pressed downwards to the position "ON", and the solution contained therein will be brought up to the temperature of 230 degrees Fahrenheit. In this way, the ammonia vapor is boiled out of the water and leaves through the pipe (No. 1a), going through the water separator (No. 9) into the condenser (No. 10). Due to the pressure and the influence of the cooling water, the vapor in the condenser is liquefied and the liquid ammonia flows through the pipes into the evaporator (No. 11). As the ammonia boils out of the water, the boiling temperature of the solution rises. When it has reached 230 degrees, the pressure of the steam in the inserted pipe (No. 5a) is sufficient to push the diaphragm (No. 5), thus moving lever (No. 6), bringing the "heating period" to an end. The heating period lasts about 1 ½ hours (the plant can be heated by either electricity, gas, paraffin oil, petrol, spirit, wood, or coal, for which cases specially constructed heaters are provided). The cooling period starts automatically at the end of the heating period and lasts for about twenty-four hours.

The water from container (No. 17) is diverted to the funnel (No. 17c) by the automatic disconnecter. From

there it passes through the cooling pipe (No. 2) through the boiler (No. 1) and the outlet pipe (No. 15). The running water causes the contents of boiler (No. 1) to be quickly cooled. At this low temperature, the water absorbs ammonia vapor, thus reducing the pressure. This reduction in pressure causes a suction from the evaporator (No. 11), which evaporates the liquid ammonia. The evaporation of the liquid ammonia causes the refrigeration. The evaporation takes about twenty-four hours, during which time the ammonia vapor flows back from the evaporator into the boiler where it is absorbed by the water. At the end of about twenty-four hours, the mixture in the boiler will again contain the same proportions of water and ammonia as at the beginning of the heating period. The evaporation of the ammonia in the evaporator produces a temperature inside the evaporator as low as minus four degrees Fahrenheit. This is sufficient to maintain an average temperature in the box of about 39 degrees Fahrenheit.

Data Folder #1183 contains all the printed pamphlets on this refrigerating machine, and anyone desiring further information should refer to this Data Folder which has quite complete instructions for installation, operation, repairs, etc.

One fact interested me particularly. Under "Installation", it is mentioned that the apparatus can be installed in any room, but the room must be free from frost

during the winter to avoid frosting the water supply. For the efficient working of the refrigerator it is naturally desirable to select not to warm a room. For this reason, it is desirable to avoid the vicinity of a hot stove or a spot where it would be exposed to the direct rays of the sun.

The paragraph "Starting the Refrigerator", is also of interest. Although the heating period ends automatically, the heating period must be started by hand. Two heating periods must never immediately follow one another. A new heating period may be started only when no frost is noticeable on the evaporator (No. 11). There must be an interval of at least twelve hours between two heating periods. Generally, heating has to be done only once a day.

Overheating is also of interest. Should the automatic disconnecter fail to cut off the electric current, then the apparatus would boil over – that is to say, not only will ammonia be driven out of the boiler (No. 1) into the evaporator, but also a certain amount of water in the form of steam. If great quantities of water are boiled over, they will not be removed in the water separator and some water will go into the evaporator. If the evaporator contains both water and ammonia, no refrigeration can take place because the contained in the evaporator absorbs the ammonia and prevents it from evaporating. This trouble can be remedied by turning the ammonia threeway tap. Immediately after the end of the period of heating, the ammonia

threeway tap (No. 14) should be turned in such a way that the handle rests firmly on the inscription "Open". The reduction in pressure in the boiler sucks the water in the bottom manifold of the evaporator back into the boiler. This return flow last about 120 minutes, during which time the ammonia tap (No. 14) should remain in the Open position, after which the ammonia tap (No. 14) should be brought back to its original position. Even if the machine does not boil over, a certain amount of water is carried into the expansion coils and the above operation should be performed regularly once a month as a precaution to insure the highest efficiency of the plant.

Since the refrigerating medium is contained in a hermetically closed system, it is never necessary to replenish the supply of ammonia or water inside the system.

APPENDIX #71-A
INFORMATION FURNISHED BY MR. STUART OTTO
ON MANNESMANN MACHINE

Mr. Stuart Otto told me that the Mannesmann booklets do not show the complete arrangement of their refrigerating machine. The hand operated lever is arranged with a stuffing box so that the tube connecting the generator with the evaporator will be above the surface of the liquid during the boiling period and will be below the surface of the liquid during the absorbing period. This is quite a complicated piece of apparatus which was patented by Dr. Rumpler. Mr. Otto had several of these Rumpler machines and experienced difficulty with this stuffing box arrangement. As described in the appendix on the Otto machine, he has a patent which does away with the necessity of this device.

Mr. Otto also said that the boxes furnished with the Mannesmann machine were very poor workmanship, and that the lining consisted of ordinary white paint on sheet metal and that the paint cracked off quite rapidly.

ARStevenson, JR-DW
February 19, 1924.

APPENDIX #72
KLEINKALTE MASCHINEN

- (1) Name of manufacturer – A. Borsig
- (2) Address – Berlin – Tegel.
- (3) Remarks – The Publication Department has a bulletin on this machine. It does not look very interesting, and is apparently a small ammonia compression machine.

APPENDIX #73

POLARIS

Manufactured by: Bayer Bros., Special Manufacturers of Small Refrigerating Machines, Augsburg, Germany.

This is an ammonia and water absorption machine. The following information is taken from their bulletin.

The box interior is automatically cooled from 35.6° to 39.2° Fahrenheit. The machine is always ready to operate without any noise or smell, or wear and tear, and without any repairs or successive refilling with refrigerant.

The supply of cooling water is as pure at the exit as at the entrance, and can afterward easily be used for other household purposes.

The Polaris can be installed anywhere where there is cold running water and electric power or gas. The installation consists merely of connecting up the water pipes and the electric or gas, after which the refrigerator is ready for use.

The voltage of the existing power system should be given when placing an order.

Size	Trade Name	Outside Measure Wide:High:Deep	Inside Measure Wide:High:Deep	Cubical Contents Useful Space: Outside Cu. Ft. : Cu. Ft.	
1	Nanson	42" : 49" : 27"	28" :32.5": 16"	8.5	32
1	Hodin	65" : 71" : 36"	51" :39.4":23.6"	27.5	160

Size	Box	Absorber	Weight-Lbs. Together	Shipping Wt.	KW-hrs. per day	Cooling Water per day
1	620	132	750	860	1.9	66 Gallons
1	1250	350	1600	1760	4.5	212 Gallons

Terms: Half the purchase price payable with the order and the rest on deliverance of shipping papers.

The Polaris has a rather interesting slogan, "Through Heat to Cold".

Description:

a- Absorber

The cooling unit proper consists of:

- 1 – Boiler
- 2 – Condenser
- 3 – Evaporator

All of these parts are firmly fastened together, but the following parts are built separately: the electrical control, the heating cartridge, two water valves and the ice cell. The boiler is shipped full and ready for use. The charge consists of water and ammonia. The heating period is started by a lever and lasts about 1 ½ hours. The heat causes almost complete evaporation of the ammonia which, in the form of vapor, is driven to the condenser. The condenser is in the form of a double pipe spiral, where the gas is liquefied by a counter current of cold water. The liquid ammonia collects in the evaporator which is arranged inside the refrigerator box. When a certain high temperature in the boiler is arrived at, the heat is automatically shut off and cold water is deflected, so that it no longer runs through the condenser, but instead runs through the cooling pipes in the in-

terior of the boiler. The weak solution of ammonia and water in the boiler tries to saturate itself with ammonia, and thus, the ammonia vapor is sucked back from the evaporator. This absorption causes the evaporation of the liquid refrigerant in the evaporator and thus cools the refrigerator box. The evaporator itself reaches a temperature below freezing and this causes the fresh water in the ice cell to freeze. The evaporation or absorption period lasts about 22 hours.

b- Box

The refrigerator box "Polaris" is solid and beautiful, built with 4 $\frac{3}{4}$ " strong pressed cork insulation. The interior is covered with white enamel on pressed artificial stone, or covered with strong glass. The box is shipped complete with the absorber ready for operation.

The description of this machine sounds very similar to the Mannesmann. I should not be surprised but that it will turn out that it is built under the same Rumpler patents. Neither the Mannesmann description nor the Polaris description mentions the most important feature of Dr. Rumpler's patents, namely the movable pipe which, during the heating period, is above the surface of the liquid in the boiler and acts as outlet for the ammonia vapor, and which, during the cooling period, is below the surface of the liquid in the boiler and acts as the inlet for the ammonia vapor during the absorption period. The fact that this machine is started by means of a lever elads me to believe that this lever probably operates such a device through a stuffing box.

ARStevenson, Jr-DW

February 29, 1924.

APPENDIX #74
HACCIUS & BISCHOF

French patent #564,622, granted to the above men on January 8, 1924, has the following claim.

An electrically driven refrigerating machine in which the driving motor is enclosed in a space separate from the outside air, and filled with an inert gas which is inoffensive to the operation of the motor. This motor compartment is in open communication with the interior of the refrigerating machine, so that the pressure of the gas in the motor compartment will conform itself to the pressure of the refrigerant, so that any of the refrigerant penetrating into the motor compartment will be in a super-heated state.

The machine can be made in several different ways, as follows:

1 – The air or inert gas in the motor compartment is separated from the refrigerant by a neutral fluid, the specific gravity of which is less than that of the liquid refrigerant – for example – oil. This liquid will prevent, to a certain extent, the interpenetration of the refrigerant with the inert gas or air in the motor compartment, while at the same time it will allow the pressure to equalize.

2 – The motor compartment, filled with air or inert gas, is in open communication with either the compression

or expansion part of the refrigerating machine by an equalizing pipe.

3 – The motor compartment, filled with air or gas, is surrounded by a space filled with liquid, or is surrounded by a compartment filled with the refrigerant, so that any small losses through the pores of the metal or joints will be from a compartment containing the refrigerant and will prevent a loss of the charge to the outside.

4 – The shaft between the motor and compressor turns in a bath oil which serves as a liquid seal between the refrigerant and the charge of air in the motor compartment.

ARStevenson, Jr-DW

February 29, 1924.

END OF APPENDIX SECTION

END OF DOCUMENT