CONTACT-EXPANSION CHILLING AND DEWAXING OF A LUBRICATING OIL STOCK USING DICHLORODIFLUOROMETHANE

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By

WALTER W. BEAM

Bachelor of Science

Texas Agricultural and Mechanical College

College Station, Texas

1946

and

JOHN B. HAMBLETON, JR.

Bachelor of Science

University of Oklahoma

Norman, Oklahoma

1947

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APPROVED BY:

R B Ewin
Chairman, Thesis Committee

B. M. Aldrich
Member of the Thesis Committee

R E Wenn
Head of the School

D. C. W Sutherland
Dean of the Graduate School

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PREFACE

One phase of the petroleum refining industry is the production of lubricating oils. The blending stocks used in making a finished lubricating oil are the high boiling fractions of a paraffin base crude oil. These high boiling fractions contain a percentage of wax which is in excess of that amount required for the blending stocks to meet the established physical specifications, and most of the wax must be removed from the blending stock oils.

There are in use at this time several methods of oil dewaxing; i. e., pressing and sweating, centrifuging; and the newer rotary-type enclosed continuous filters used with special solvents, such as acetone-benzene, trichlorethylene, ethylene dichloride-benzol (Barisol), and particularly propane and methylethyl ketone-benzol (MEK).

For a modern solvent refining lubricating oil plant with an MEK dewaxing unit, one piece of essential equipment is a double-pipe scraped surface heat exchanger for use with direct-expansion ammonia to chill the oil. The scraper is necessary to keep the heat transfer surface free of wax at all times. The mechanical scrapers used in modern double-pipe heat exchangers are a source of trouble and high maintenance costs.

It has been noted that some refrigerants will mix with lubricating oils in compressor service on low temperature work and keep the oils from dewaxing. The question arose of whether a refrigerant could be used in contact-expansion to provide the required chilling of the oil and also to serve as a special solvent for dewaxing the oil, thereby replacing the mechanical scrapers and the ammonia chillers.

This investigation was inaugurated with the purpose of determining whether or not Dichlorodifluoromethane ("Freon-12") could be used in contact-expansion with the oil for chilling, and if the refrigerant would act as a dewaxing solvent.

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INTRODUCTION

There are so many uses for mineral oils that a formidable array of names based on uses has arisen, but in general, lubricating oils can be divided into several groups such as engine and machine oils, compound oils, turbine oils, cold test oils, transformer oils, color oils, and corrosive oils. This investigation is concerned primarily with the first group of lubricating oils listed — the engine and machine oils.

In the manufacture of engine and machine oils, a variety of specifications must be met to provide suitable oils for the different required services. The finished oil is a blend of several component oils (each component having a definite specification) plus the necessary "additives".

One phase of refining the so-called "component" oils consists of the removal of excess wax contained in the oils. A clearer understanding of the problems involved in dewaxing a petroleum oil may be had by referring to the following description:

> The waxy materials present in the high boiling fractions of mineral oils are now considered to be crystalline throughout but under certain conditions may behave like a colloid. A solution of petrolatum, bright stock, and naphtha, when agitated over long periods at the crystallizing temperature, will form a completely transparent jelly; but the same solution, when chilled more rapidly and with moderate agitation, will precipitate a wax that can be centrifuged but not filtered because the wax plugs the pores of the filter cloth. If the oil is dissolved in such solvents as propane or acetone, the petrolatum forms aggregates upon chilling which are easily separated by filtration.[1]

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[1] Nelson, W. L. Petroleum Refinery Engineering, p. 319.

The scraped surface of the heat exchanger in the double-pipe chiller is required in a modern solvent refining plant to keep the solidified wax off this surface in order to facilitate heat transfer and fluid flow. If a solvent were available which would carry the wax, after being chilled, in solution to the point of filtration and then permit the wax to be filtered, the mechanical scraper could be eliminated. With this thought in mind, consider the following:

> There are no commercially available lubricants which have satisfactory viscosities at normal temperatures, in which the pour and dewaxing points are lower than -20 or -30 F. It has been found that there are several high-grade lubricants having satisfactory characteristics which do not congeal or dewax to any appreciable extent, provided that they carry in solution a reasonable proportion of liquid refrigerant.[2]

With the information from the above quotation, it was decided to try "Freon-12" as the refrigerant "carrier" to keep the wax in solution to the point of filtration.

Since this investigation is to determine whether or not "Freon-12" can be used in contact-expansion to replace the double-pipe chillers, a typical oil being charged to a MEK dewaxing unit through a double-pipe chiller will be used. Figure 1 is a flow diagram showing the process path this oil follows as it is "cut" out of the crude oil and treated to the point of entry into the MEK dewaxing unit. Table I gives a laboratory analysis of the oil before and after dewaxing in a methylethyl Ketone-benzol solvent refining unit referred to as a MEK unit. The flow diagram, Figure 1; the laboratory analysis of the oil, Table I; and the oil used in this investigation were

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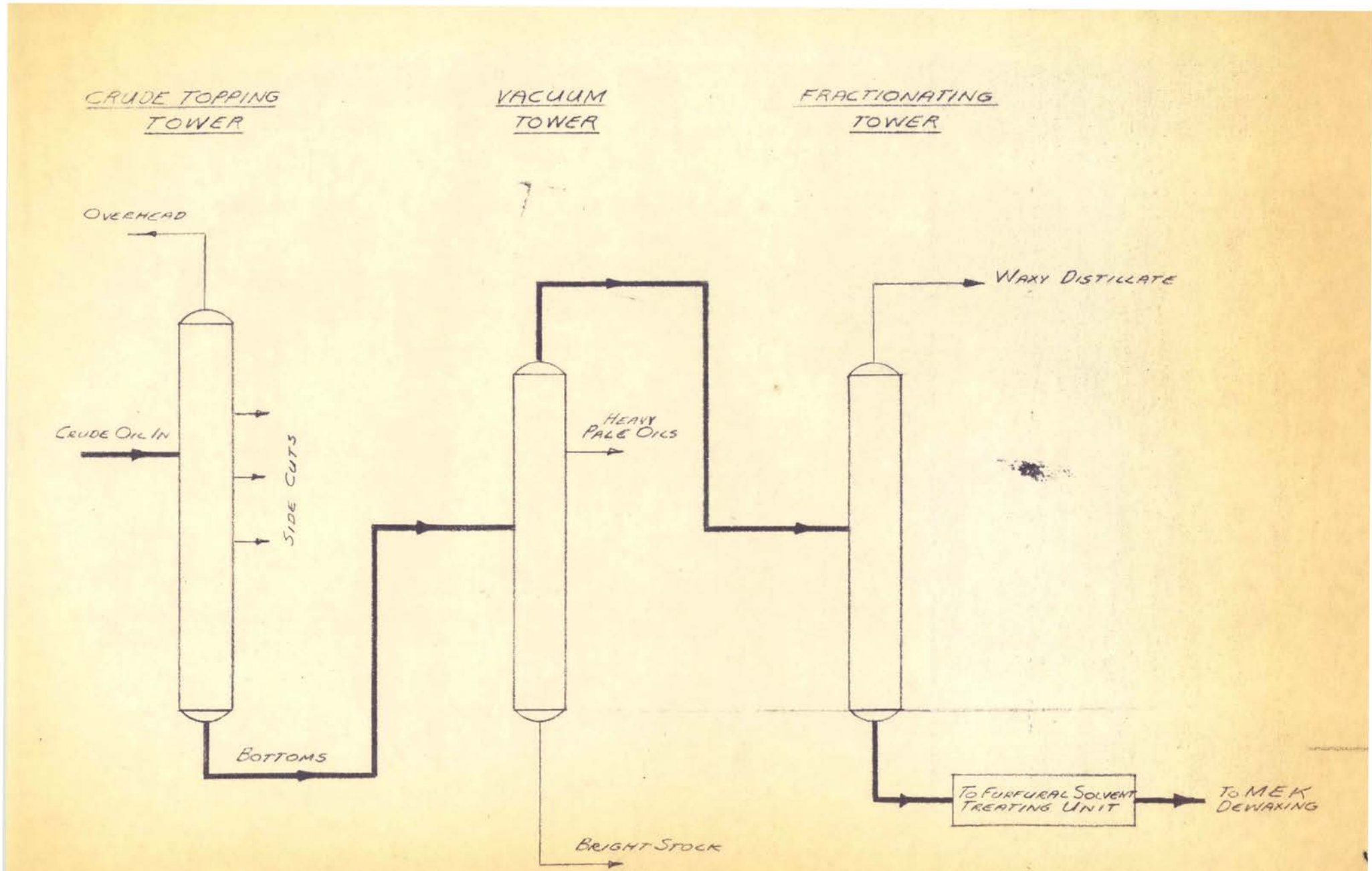
[2] American Society of Refrigerating Engineers. Refrigeration Data Book, Refrigeration Applications Volume, p. 550.



PALE OIL FLOW DIAGRAM

FIG 1

TABLE I

Laboratory Analysis of Pale Oil Charged to MEK Dewaxing Unit

Before Dewaxing

Gravity, °A.P.I.		33.3
Flash, P.M., °F.		440.0
Viscosity		
S.S.U. @ 100° F.		138.6
S.S.U. @ 210° F.		43.1
Viscosity Index		115.8
Viscosity Gravity Constant		0.804
Cold Test, °F.		+ 88.0
Color, A.S.T.M.		1.0 -
Wax Content, Weight %		14.6
Furfural Content, Volume %	less than	0.0034

After Dewaxing

Gravity, °A.P.I.		32.2
Viscosity		
S.S.U. @ 100° F.		172.0
S.S.U. @ 210° F.		44.6
Viscosity Index		98.8
Viscosity Index Corrected to 0° F.		99.2
Cold Test, °F.		- 2.0
Viscosity Gravity Constant		0.808

from the Continental Oil Company Refinery in Ponca City, Oklahoma. This type oil is dewaxed in the MEK unit between the temperatures of -6° F. and -10° F.

In Table II is tabulated the relation between temperature and pressure for "Freon-12" and the following is a general description of the refrigerant.

> Dichlorodifluoromethane, also known as "Freon-12" or "F-12", is used extensively as a refrigerant in comfort air-conditioning installations. "Freon-12" is one of the so-called halogenated-hydrocarbon refrigerants and its chemical formula can be written from its chemical name by starting with the formula for methane (CH_4) and replacing the hydrogen atoms with the proper number of chlorine and fluorine atoms. Thus the formula appears CCl_2F_2.
>
> "Freon-12" has a moderate pressure range. Its latent heat is low, 50 to 85 B.t.u. per pound, so that the weight of "Freon-12" circulated per minute per ton of refrigeration is higher than for some of the other refrigerants. It has a critical temperature of 232.7° F. at 582 pounds per square inch absolute.
>
> "Freon-12" is chemically stable and has practically no corrosive effects on ordinary metals unless contaminated by impurities. This refrigerant is noncombustible, although in the presence of open flames or very hot surfaces it breaks down and forms toxic gases. It is almost perfectly non-toxic even in concentrations above 20 per cent by volume of air, and has only a very slight odor. No special piping is required to handle "Freon-12" in normal installations. Rubber gasket material is inadvisable to use with most halogenated-hydrocarbon refrigerants, but various synthetic gasket compositions (neoprene) are satisfactory in nearly all cases.[3]

With this basis of knowledge and information, in determining whether or not "Freon-12" could be used in contact-expansion for chilling the oil and if "Freon-12" would act as a solvent to keep the wax in solution to the point of filtration, it was decided to conduct the necessary experiments in two phases. Phase 1 tests were conducted at atmospheric pressure and the corresponding temperature for the "Freon-12" and oil mixture, and Phase 2

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[3] Jennings, B. H. and S. R. Lewis. Air Conditioning and Refrigeration, pp. 393-394.

TABLE II

Pressure Temperature Relations of "Freon-12"[4]

Temperature °F.	Pressure PSIA
- 40	9.32
- 30	12.02
- 20	15.28
- 10	19.20
0	23.87
+ 10	29.35
+ 20	35.75
+ 30	43.16
+ 40	51.68
+ 50	61.39
+ 60	72.41
+ 70	84.82
+ 80	98.76
+ 90	114.3
+100	131.6

[4] Ibid.

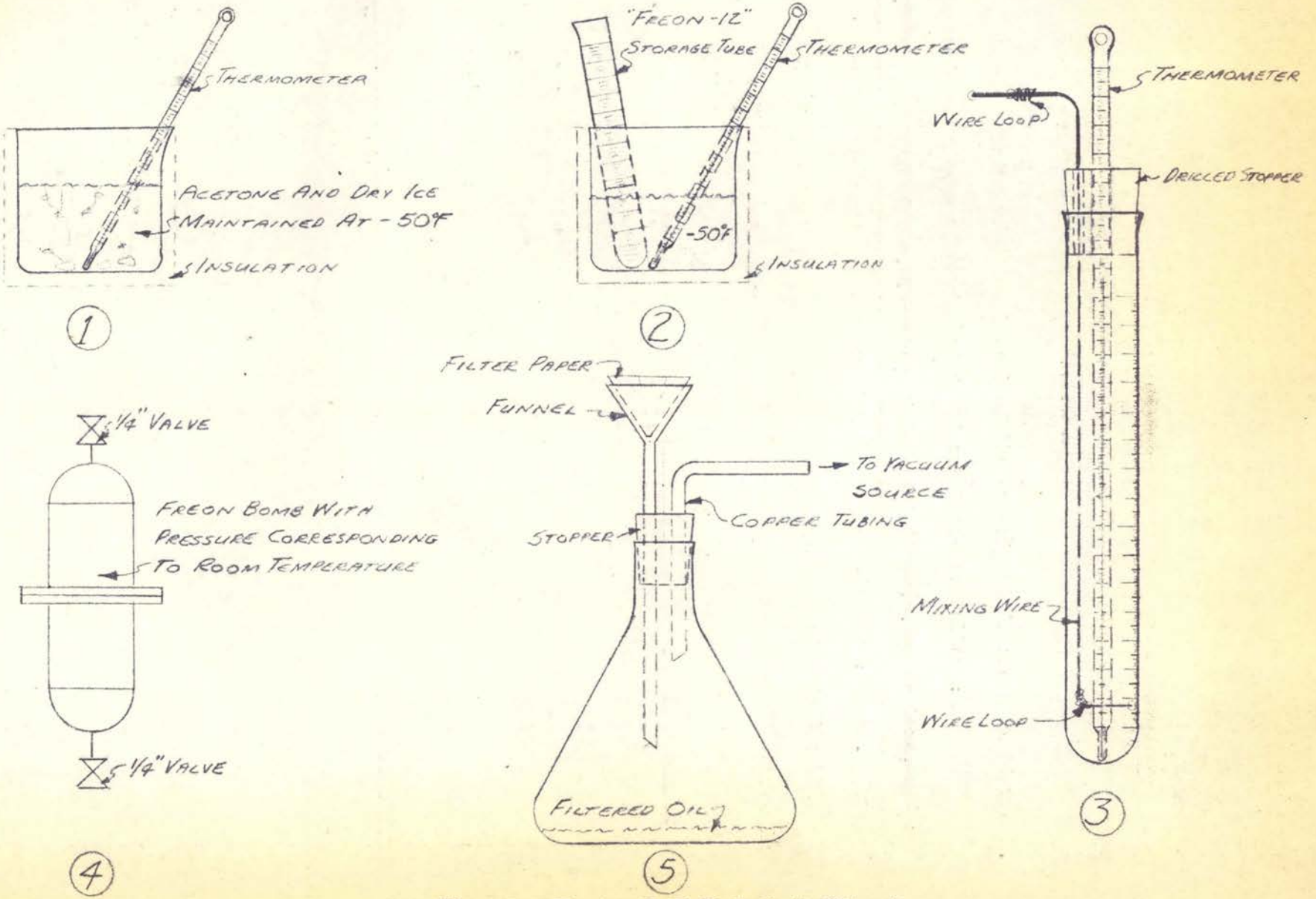
tests were conducted at increased pressures and the corresponding temperatures for the "Freon-12" and oil mixture.

APPARATUS

Phase 1

The apparatus used in Phase 1 of the experiment is shown in Figure 2. The numbered pieces of equipment in Figure 2 are as follows:

1. An insulated 500 c.c. beaker filled with 300 c.c. of acetone, and a low temperature thermometer with a range of -100 to + 50 °F. Crushed dry ice was added to the acetone as required to maintain the bath temperature at -50°F. This cold bath was used as the cold source in chilling the oil and "Freon-12" mixture.
2. The equipment required to keep the "Freon-12" in a liquid state at atmospheric conditions; an insulated 500 c.c. beaker filled with 250 c.c. of acetone, a low temperature thermometer with a range of -100 to +50°F., and a 200 c.c. tube for "Freon-12" storage while doing experimental work. Crushed dry ice was added to the acetone as was required to maintain the bath temperature at -50°F.
3. A 100 c.c. graduated glass tube, a low temperature thermometer with a range of -100 to +50°F., a 12 Ga. steel wire bent to form a mixer, and a cork to fit the glass tube perforated for passage of the thermometer and mixing wire.
4. A one quart size bomb valved for storage and transporting of "Freon-12".
5. A 500 c.c. glass flask, a long stem plastic funnel, a piece of 1/8 inch copper tube bent to form a suction connection to a vacuum source hose, a rubber stopper perforated for the passage of the funnel stem and copper tube, and medium weight filter papers.



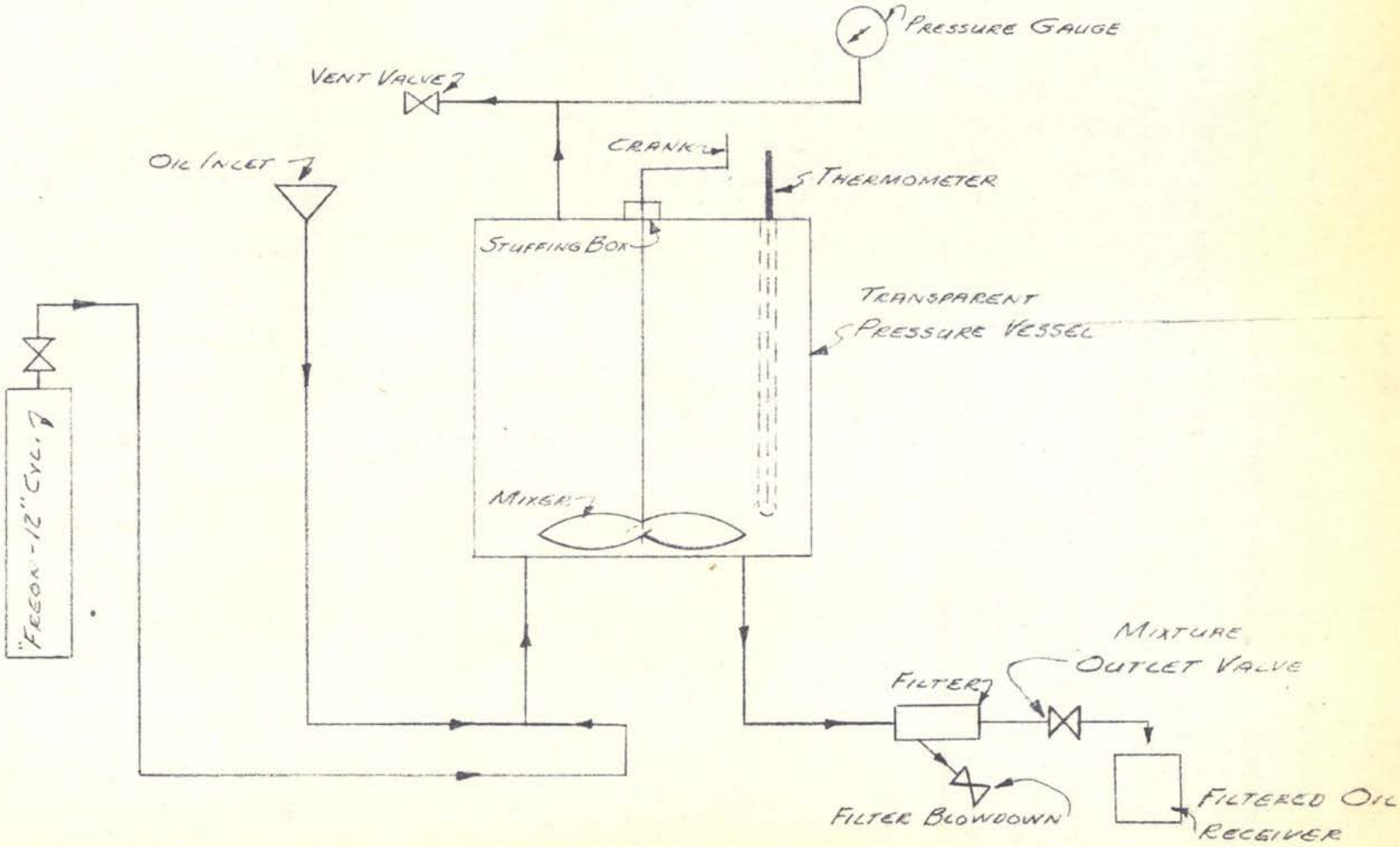
PHASE 1 APPARATUS

FIG. 7

Phase 2

Figure 3 is a flow diagram of Phase 2 operations and Figures 4, 5 and 6 show the apparatus used in Phase 2 of the experiment. The numbered pieces of equipment in Figure 4 are as follows:

1. Two six-inch 150 pounds per square inch American Standards Association raised face blind flanges with a groove machined to take a rubber gasket and fit the plexiglass cylinder. These flanges were drilled and tapped to take part of the piping connections shown, and the other connections were welded to the flanges.
2. Four 5/8 inch diameter bolt studs for seating the flanges on the plexiglass cylinder.
3. A 5 3/4 inch inside diameter plexiglass cylinder, six inches long. This cylinder has a bursting pressure of 125 pounds per square inch.
4. A mixer made of a $\frac{1}{4}$ inch diameter steel rod bent to form a handle, with a strip of 1/8 inch plate steel $\frac{1}{2}$ inch wide and 5 inches long welded to the lower end of the rod.
5. A stuffing box made by welding a $1\frac{1}{2}$ inch coupling to the flange, screwing a plug into the coupling, and drilling both the coupling and flange with a 9/32 inch drill for the passage of the mixer rod. The stuffing box was packed with graphite impregnated asbestos rope packing.
6. A $\frac{1}{4}$ inch thermowell made by closing one end of a $\frac{1}{4}$ inch pipe nipple by welding. The nipple was screwed into a tapped hole in the top flange and filled with "Zerex" anti-freeze.
7. A thermometer with a range of 0 to 100° F.
8. A graduated scale on the outside of the plexiglass cylinder. This scale was made of drafting tape with the graduation marks added after the tape was placed on the cylinder.



PHASE 2 FLOW DIAGRAM

FIG 3

PHASE 2 APPARATUS
FIG 4

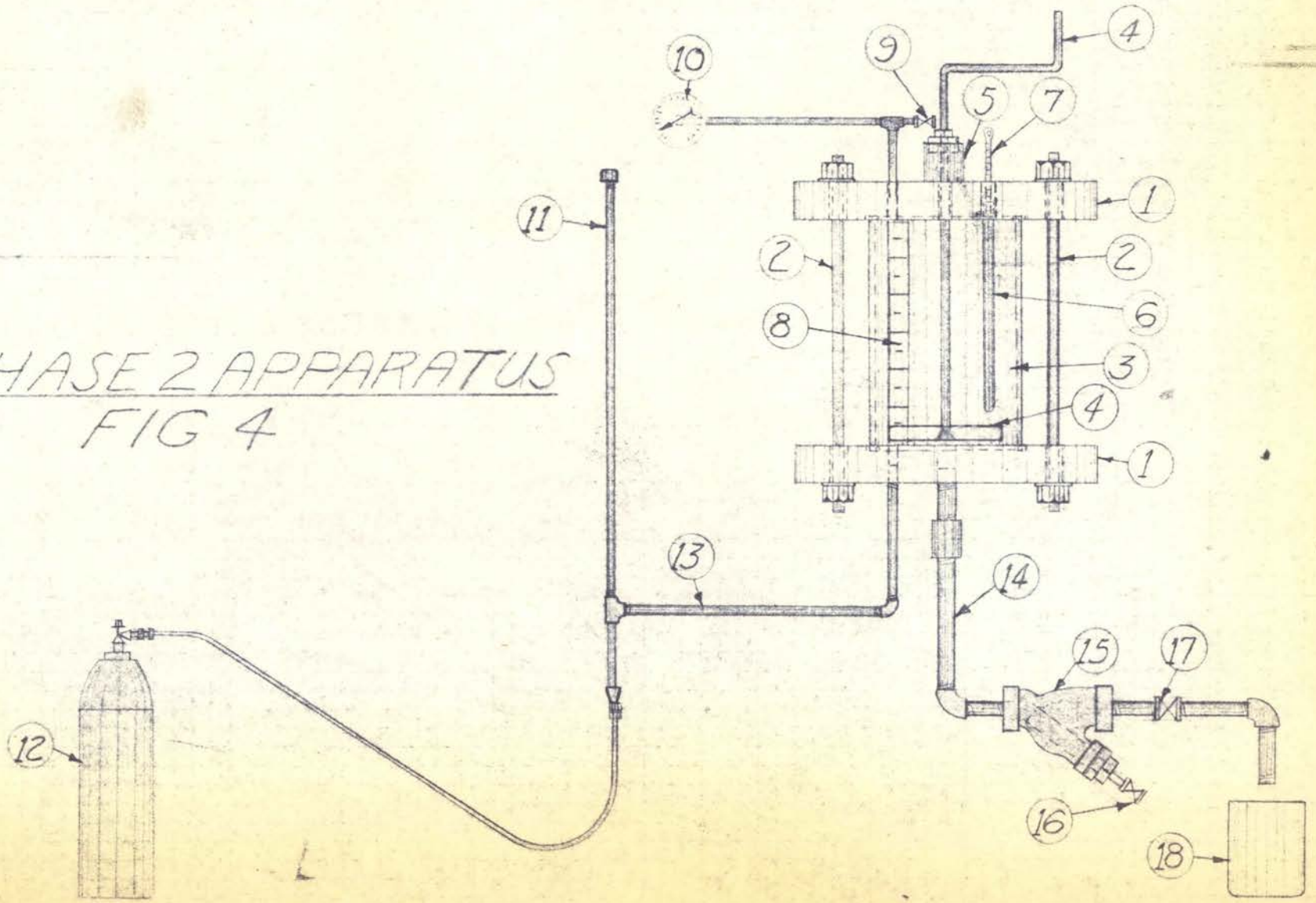


Figure No. 5

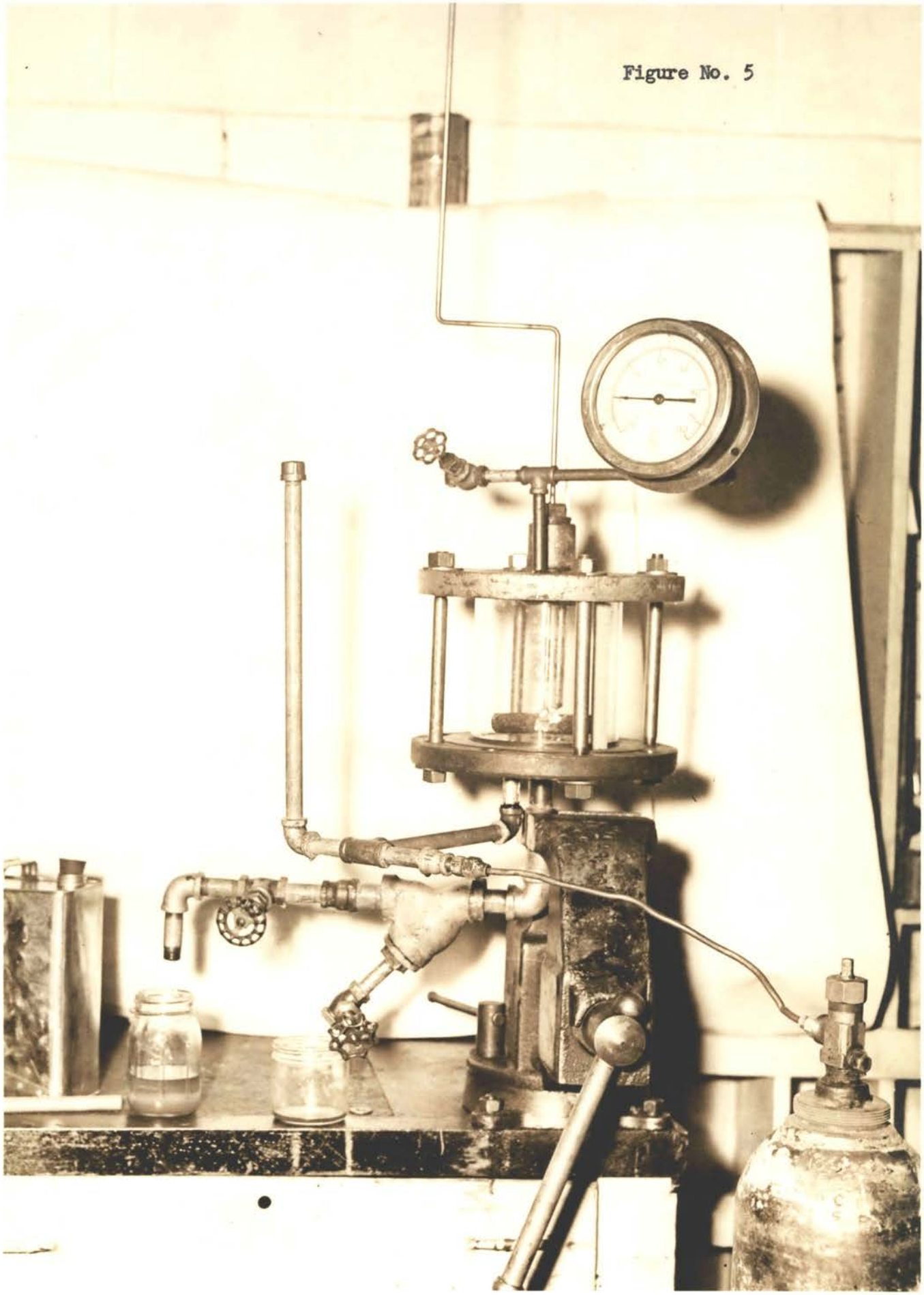


Figure No. 6

9. A $\frac{1}{4}$ inch needle valve vent.
10. A refrigeration pressure gauge with a range of -30 inches of mercury to 150 pounds per square inch.
11. A 3/8 inch oil inlet line.
12. A "Freon-12" storage bottle containing 25 pounds of "Freon-12" at atmospheric temperature.
13. A 3/8 inch combination oil and "Freon-12" inlet line.
14. A 3/4 inch mixture (oil and "Freon-12") outlet.
15. A filter made by using a 3/4 inch steam line strainer. The perforated strainer screen was wrapped on the inside with medium weight canvas to form the filtering surface.
16. A 3/8 inch globe valve mixture drain for strainer blowdown.
17. A $\frac{1}{2}$ inch globe valve filtered oil and "Freon-12" mixture drain.
18. A one pint jar for catching the filtered oil and "Freon-12".

The piping apparatus was assembled as shown in Figures 4, 5 and 6, and all joints were coated with pipe joint sealer.

EXPERIMENTAL PROCEDURE

Phase 1

The first step in attempting to mix the oil and the "Freon-12" was to pour 8 c.c. of oil into the 100 c.c. graduated tube. Liquid "Freon-12" was then poured into the test tube with the oil at room temperature. Part of the "Freon-12" immediately vaporized, but part remained liquid. As the first liquid "Freon-12" touched the oil, the "Freon-12" immediately vaporized and the top four c.c. of the oil was solidified which prevented mixing of the oil and "Freon-12".

It was decided to first chill the oil to a temperature of -30°F., (by alternately inserting the tube in the cold bath and removing, to maintain the temperature at -30°F. as indicated by the thermometer in the oil) at which point the oil is a solid, then add "Freon-12" gradually, and mix the "Freon-12" and solid oil to see if the "Freon-12" would dissolve the solid oil with the mixture at a temperature of -30°F. The temperature of -30°F. was selected to be certain none of the "Freon-12" would evaporate.

In the second test, 8 c.c. of oil was poured into the 100 c.c. tube and 20 c.c. of "Freon-12" was added slowly while the oil and "Freon-12" were being mixed. By the time that 20 c.c. of liquid "Freon-12" had been added, all of the solid oil and wax had been dissolved. To determine just what the ratio of "Freon-12" to oil had to be, at -30°F., in order to keep the wax and oil in a liquid state, the temperature of the oil was increased slightly to evaporate a portion of the "Freon-12". When two c.c. of the "Freon-12" had been evaporated, small particles of congealed oil appeared in the

solution. One c.c. of "Freon-12" was added and the particles disappeared. This procedure was tried three times, and each time the ratio of "Freon-12" to oil at -20°F. was 19 c.c. of "Freon-12" to 8 c.c. of oil, or 2.3 to 1, in order to keep the wax and oil in a liquid state.

The solution of oil and "Freon-12" was then poured into the filter paper in the funnel to see if the "Freon-12" would remain in solution long enough for the solution to be filtered without using the vacuum connection of the filter flask. As soon as the solution of oil and "Freon-12" was poured into the filter paper, the "Freon-12" began evaporating, and this evaporation was so fast that the solution was converted to a mass of bubbles and foam. The foam appeared to be made up of oil bubbles filled with "Freon-12" gas. A stirring rod was used to agitate the foam and eventually all of the bubbles were gone. By this time the remaining solution was again at room temperature and the solution appeared to be nothing more than the original oil sample. A few drops of the remaining oil passed through the filter paper, but there was no wax filtered out, as the wax was in solution with the oil.

Another measure of 8 c.c. of oil was chilled to a temperature of -30°F., 19 c.c. of "Freon-12" added, and the mixture agitated until it was a homogenous solution. The vacuum hose was attached to the connection on the filter flask and the oil and "Freon-12" solution was poured into the filter paper. The "Freon-12" again started evaporating and forming foam, but part of the solution was drawn through the filter paper before it had begun the foaming. The solution that was drawn through the filter paper into the flask turned to foam immediately upon dropping into the flask due to the evaporation of the "Freon-12" caused by increased temperature and the decreased pressure of the vacuum system.

The foam was taken from the filter paper and stirred until all of the bubbles disappeared to form one sample, and the foam inside the filter flask was stirred to form another sample. The two samples were placed in a cold room at 40°F. and observed. It was noted that both samples congealed at approximately the same time and both congealed above 40°F. which would indicate that there was no appreciable difference in the amount of wax in either sample, in other words, none of the wax was being filtered.

A fourth solution was prepared. This time 25 c.c. of "Freon-12" was added to 8 c.c. of oil in order to have a surplus of "Freon-12" to try and decrease the effects of foaming in the filtering operation. This solution was filtered with the same results as before except that the foaming appeared to have increased with the addition of excess "Freon-12". The oil that passed through the filter paper appeared to have the same amount of wax in it as the oil from on top the filter paper upon observing the two samples in the cold room.

A fifth solution was mixed having 8 c.c. of oil and 30 c.c. of "Freon-12" to further test the effect of excess "Freon-12" on the filtering operation. This solution was filtered, again using the vacuum, and it was noted that the foaming definitely increased with a surplus of "Freon-12". Two separate oil samples were prepared from the foam on the filter paper and the foam inside the filter flask. Upon checking the congealing temperatures of the two samples, it was found that, as before, no appreciable amount of wax had been filtered.

For verification of results a sixth solution of oil and "Freon-12" was prepared with 8 c.c. of oil and 19 c.c. of "Freon-12". This solution was filtered with the vacuum system and again foam appeared inside the flask and on the filter paper. Two samples were prepared from the foam again and were

checked in the cold room. Again the results were the same; no wax was filtered.

To further check the mixing characterisitcs of the oil and "Freon-12", a seventh solution was prepared with 8 c.c. oil and 19 c.c. of "Freon-12". This solution was chilled to a temperature of -50°F. and although the solution apparently became more viscous, it appeared that no wax particles were formed. The solution was then warmed to a temperature of -30°F. and further warmed slowly to room temperature to allow the "Freon-12" to evaporate at a very slow rate. When the sample finally reached room temperature there was no foam since the "Freon-12" evaporation had been controlled at a very slow rate. The remaining sample measured just slightly above 8 c.c. which indicated that nearly all of the "Freon-12" had evaporated, leaving just a slight trace of "Freon-12" in the original oil sample.

Phase 2

The apparatus constructed for Phase 2 of the experiment, as shown in Figures 4, 5 and 6, was tested at a pressure of 75 pounds per square inch gauge. This was done by closing all valves in the piping system and slowly opening the valve on the "Freon-12" supply cylinder. It was noted that the vent valve was leaking and the bonnet on this valve was tightened, which stopped the leak. The pressure in the vessel was again increased slowly to 75 p.s.i.g. and the valve on the "Freon-12" supply closed. After five minutes it was noted that the pressure as indicated by the gauge had not decreased and it was assumed that all joints were tight.

A small quantity of oil was poured into the pressure vessel through the oil inlet with the vent valve open, and then the mixture outlet valve

and the filter drain valve were opened one at a time, until oil ran out of those valves to fill the lower part of the system with oil. All valves were checked and closed, except the vent valve which was left open, and 39 cubic inches of oil were poured into the vessel. (This 39 cubic inches was indicated by the scale on the plexiglass cylinder and did not include the oil in the lower piping part of the system.) The oil inlet line was then closed.

With the vent valve remaining partially open the valve on the "Freon-12" supply cylinder was opened slowly and "Freon-12" gas bubbled up through the oil. The pressure increased to 15 pounds per square inch gauge but the oil level did not increase appreciably which indicated that no great amount of liquid "Freon-12" was going into solution with the oil. It was decided that the "Freon-12" supply cylinder would have to be inverted in order to introduce liquid "Freon-12" into the oil.

The "Freon-12" supply cylinder was inverted and the valve again opened until the pressure in the pressure vessel reached 15 p.s.i.g. with the vent valve still partially open.

Again the liquid level in the pressure vessel did not increase, so the valve on the refrigerant supply cylinder was opened further. The level in the pressure vessel started rising and the pressure began increasing. The vent valve was operated to control and maintain the pressure on the system below 70 p.s.i.g. While the liquid "Freon-12" was being added to the oil, the mixer was turned to keep the solution well agitated.

The liquid "Freon-12" was added to the system until a total of 39 cubic inches had been added. At this point the scale on the plexiglass cylinder indicated a total of 78 cubic inches. A slight amount of foam developed at the top of the liquid level due to the vaporizing and venting off of part of the "Freon-12".

When the scale on the plexiglass cylinder indicated 78 cubic inches (which was a "Freon-12" to oil ratio of 1 to 1) the vent valve was closed, the "Freon-12" supply cylinder closed, and the pressure and temperature noted as being 67 p.s.i.g. and 74°F. The vent valve was then opened to reduce the pressure on the system, vaporize and vent off part of the "Freon-12", and chill the remaining solution of oil and "Freon-12".

As the vent valve was opened it was noted that foam began forming at the liquid level. The mixer was turned continuously which served to keep the foam at the top. When there was just 26 cubic inches of liquid in the pressure vessel (the rest of the solution had been converted to foam), the pressure was 30 p.s.i.g. and the temperature was 58°F. At this point the remaining liquid was filtered.

To filter the solution, the filter blowdown valve was opened to drain off the oil in the piping below the pressure vessel which had not been mixed with "Freon-12". This valve was closed, and then the mixture outlet valve was opened. A small amount of oil was drained out of the mixture outlet line to get rid of the oil in the piping that was not in the pressure vessel, then the filtered mixture was caught in the filtered mixture receiving jar. The mixture of oil and "Freon-12" that came through the filter was in a foamy condition at the outlet. It was assumed that the oil and "Freon-12" mixture passed through the filter as a liquid and then bubbles formed after changing from the filter pressure of 30 p.s.i.g. to atmospheric pressure due to the entrained "Freon-12" expanding.

After a small amount of the mixture had passed through the filter, the pressure on the system was reduced to atmospheric and the filter element removed. The filter element was full of foam identical in appearance with the foam that formed in the oil receiving jar. The foam was scraped off

the filter cloth and placed in a jar. When the foam in the oil receiving jar and the foam which was formerly in the filter had both been stirred to break the bubbles and form liquids, the two samples appeared to be the same and the oil from the foam in the filter did not show any traces of wax.

The foam was cleaned from the inside of the pressure vessel and the system was flushed with fresh oil in preparation for another test run. This time 13 cubic inches of oil was poured into the pressure vessel through the oil inlet line with the vent valve open. Some oil was drained through the filter blowdown valve and mixture outlet valve before they were closed. Then more oil was added until the scale on the plexiglass cylinder indicated 13 cubic inches of oil, and the oil inlet line closed.

The "Freon-12" supply cylinder was inverted and the valve on this cylinder opened to introduce liquid "Freon-12" into the pressure vessel. Again the vent valve was operated to control and maintain the pressure on the system below 70 p.s.i.g. Liquid "Freon-12" was added until the scale on the plexiglass cylinder indicated a total of 78 cubic inches of solution, which meant that 65 cubic inches of liquid "Freon-12" had been added which was a ratio of 5 to 1, "Freon-12" to oil. While the liquid "Freon-12" was being added, the mixer was turned continuously. The "Freon-12" supply cylinder valve was closed and the conditions in the pressure vessel were noted as being 70 p.s.i.g. and 75°F.

The vent valve was opened further to reduce the pressure, in order to vaporize and vent off a portion of the "Freon-12", and chill the solution. When 39 cubic inches of liquid and foam remained in the pressure vessel, the pressure in the vessel was 10 p.s.i.g. and the temperature 25°F. At this point the vent valve was closed and the mixture was filtered as in the

previous run, by first draining the oil from the lower piping of the system, then passing the liquid and foam mixture through the filter.

As in the previous run the oil and "Freon-12" mixture that passed through the filter emerged in a foamy condition. After a portion of the oil had been filtered, the pressure on the system was reduced to atmospheric and the filter element removed. Although the filter contained what appeared to be foam, there seemed to be some wax present on the filter cloth. The oil that had passed through the filter was stirred to break the foam bubbles and form a liquid. This liquid was placed in a refrigerated space and it was noted that the oil congealed above 35°F. Referring to Table I, it can be seen that the congealing temperature of a similar oil dewaxed in a MEK unit is -2°F. This comparison indicates that only a very small amount of wax has been filtered.

Due to the heat gain of the chilled mixture from the surrounding atmosphere, it seemed impossible to reach a temperature lower than 25°F. and still maintain a pressure on the system. A check run was made to verify this minimum temperature. It was believed that the pressure on the system would offset this filtering temperature which is higher than the MEK unit filtering temperature, since the MEK unit filters the wax under vacuum conditions.

While cleaning the pressure vessel after the first test, it was noted that foam from the previous test could be reverted to a liquid by increasing the pressure. When this pressure was released suddenly the foam reappeared, but when released gradually, no foam was formed.

DISCUSSION OF EXPERIMENTAL RESULTS

The purpose of this experimental work was to determine whether "Freon-12" could be used in contact-expansion with the oil for chilling, and if the refrigerant would act as a dewaxing solvent. During the course of the before described experimental operations, several problems were encountered which can be answered only by further experimental work with a more elaborate apparatus.

The most serious problem was that of foaming, which arose when "Freon-12" was evaporated from the oil and "Freon-12" mixture. Possibly there exists an "anti-foam" agent which could be introduced into the oil and the "Freon-12" mixture to reduce the surface tension of the oil and prevent the formation of "Freon-12" bubbles. However, before such an "anti-foam" agent is tested, the effect of the agent on the finished oil should be known, and also a study of the economics of using such an agent should be made. Certainly some method must be devised which will permit the evaporation of "Freon-12" from the mixture without foaming.

Since it appears, from the experimental work previously described, that the "Freon-12" can be used in contact-expansion for chilling the oil, but is unsuitable as a dewaxing solvent; if the problem of foaming can be overcome, perhaps a known dewaxing solvent, such as propane, acetone-benzene, etc., can be introduced at the point of filtering in order to precipitate the wax in the solution. However, this process would require a more intricate apparatus and a means of separating the solvent from the "Freon-12", after the solvent and "Freon-12" had been separated from the filtered oil.

One of the factors that interferred with obtaining the desired results was the foaming condition of the mixture. However, had the apparatus used in Phase 2 been insulated and cooled to minimize the effects of heat gained from the surroundings, more conclusive results may have been obtained. The apparatus was not insulated since visual observation of the mixing operation was required. An alternate procedure would be conducting the experiment in a cold room, but then congealing of the oil would have been encountered which would delete the experimental test of contact-expansion.

CONCLUSIONS

After completing the experimental work previously described and analyzing the results, we are able to conclude that "Freon-12" and the oil used were perfectly miscible, providing the proper ratio of "Freon-12" to oil was maintained, and that "Freon-12" can be used in contact-expansion for chilling an oil of this type.

Further we may conclude that within the limits of the investigation, "Freon-12" alone is not a suitable dewaxing solvent for this type oil.

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NAME OF AUTHORS: Walter W. Beam and John B. Hambleton, Jr.

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NAME OF TYPIST: Dorothy Watkins