American Institute of Chemical Engineers

STUDENT CONTEST PROBLEM

1971

345 East 47 Street • New York, New York 10017

CONTEST PROBLEM

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AMERICAN INSTITUTE OF CHEMICAL ENGINEERS STUDENT CHAPTERS

Open Only to Undergraduates or Those
Without a Degree in Chemical Engineering

DEADLINE FOR MAILING

Solution must be postmarked not later than midnight, June 15, 1971

RULES OF THE CONTEST

Solutions will be graded on (a) substantial correctness of results and soundness of conclusions, (b) ingenuity and logic employed, (c) accuracy of computations, and (d) form of presentation. Accuracy of computations is intended to mean primarily freedom from mistakes; extreme precision is not necessary.

It is to be assumed that the statement of the problem contains all the pertinent data except for those readily available in handbooks and similar reference works. The use of textbooks, handbooks, journal articles, and lecture notes is permitted. In cases where there is disagreement in the data reported in the literature, the values given in the statement of the problem have been chosen as being most nearly applicable.

The problem is not to be discussed with any person whatever until June 15, 1971. This is particularly important in cases where neighboring institutions may not begin the problem until after its completion by another chapter. Submission of a solution for the competition implies adherence to the foregoing condition.

A period of not more than 30 consecutive days is allowed for completion of the solution. This period may be selected at the discretion of the individual counselor, but in order to be eligible for an award a solution must be postmarked not later than midnight, June 15, 1971.

The finished report should be submitted to the chapter counselor within the thirty-day period. There should not be any variation in form or content between the solution submitted to the chapter counselor and that sent to the AIChE office. The report should be neat and legible, but no part need be typewritten.

The solution should be accompanied by a letter of transmittal giving only the contestant's name, school address, home address, and student chapter, lightly attached to the report. This letter will be retained for identification by the Secretary of the Institute. The solution itself must bear no reference to the student's name or institution by which it might be identified. In this connection, graph paper bearing the name of the institution should be avoided, as should paper with a watermark identifying the school.

Each counselor should select the best solution or solutions, not to exceed two, from his chapter and send these by registered mail to

Mr. F. J. Van Antwerpen, Secretary
American Institute of Chemical Engineers
345 East 47 Street
New York, New York 10017

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STATEMENT OF THE PROBLEM

A company in the Midwest is processing purchased crude vegetable oils into edible products. As demand has increased, the company has added new capacity which will process 20,000 lb./hr. of crude soybean oil.

You have been assigned to design the part of this expansion known as the "winterizing" section. Your report should include the following:

1. A detailed flow diagram of a chiller and refrigeration system, including the controls necessary to give any required temperature-time profiles.
2. A schematic layout of equipment, including any elevation drawings necessary to describe the plant.
3. The design of a typical chiller, including process calculations.
4. The design of the refrigeration system.
5. Recommended operating procedures.
6. A proposed operating schedule.

BACKGROUND

Vegetable oils, such as soybean oil, are mixtures of triglyceride molecules (glycerine totally esterified with various fatty acids).

To become edible, they are neutralized (caustic extracted to remove free fatty acids), hydrogenated (to adjust unsaturation), winterized (to remove solid oils), deodorized, blended, and otherwise treated in an oil refinery. Each step in refining affects subsequent steps and is affected by preceding operating steps. When free fatty acids have been removed by caustic refining, the remaining oil is often called a "neutral oil."

Most neutral oil sold in the United States is sold as salad oil, rather than cooking oil. The difference between the two is that salad oil will not solidify at temperatures of 40° to 50°F., whereas cooking oil may do so. The preference for salad oil in this country is due principally to the widespread use of mechanical refrigerators, which provide a food storage temperature of 35° to 45°F. An oil that becomes solid in the refrigerator is inconvenient to handle. For a long time soybean oils were not accepted as salad oils. However, it has been found that a fully satisfactory salad oil can be made from soybean oil. In our refinery we neutralize the crude soybean oil with a sodium hydroxide solution. The refined oil is partially hydrogenated to improve stability; then it is winterized, deodorized, and further processed for sale.

DESIGN CONCEPT

Company D has been producing edible oils for many years. Its recent sales trend has indicated that, with additional refining capacity, sales can be expanded. The company therefore has decided to expand its capacity in steps of 20,000 lb./hr. of crude vegetable oil. Naturally, the volume of each product offered to customers will depend upon the specific vegetable oil processed and the yield at each step. Crude soybean oil will be diverted to the new facilities, the older equipment thus released being used to process extra quantities of other vegetable oils as required. By designing for a specific crude oil, we hope to optimize the yield of more valuable products.

Industrywide policy calls for process operation on a three-shift-per-day, five-day-per-week basis. Storage capacity between operations will be provided so that interruptions at any point in the process will not affect adjoining operations. Five-day operation permits maintenance or cleaning on weekends. It also permits use of a limited crew for finishing a product on a Saturday or Sunday if necessary. Operations requiring minimum labor or supervision under programmed control may run over weekends. We do not plan, however, on regularly scheduling process operations from 7:00 a.m. on Saturday to 7:00 a.m. on Monday. Work shall be for 52 weeks a year with nine holidays on which no work is scheduled.

By varying conditions during hydrogenation, we expect to maximize the yield of salad oil, which nets 3 cents a pound more than cooking oil. The design of the units therefore must provide flexibility for satisfactory performance over a range of charge-stock compositions.

HYDROGENATION PLANT PRODUCT

The winterizing plant feed will come from the hydrogenation plant. This product will consist of mixed triglycerides having the following compositions:

Saturated acids	17%
Oleic acids	70
Linolenic acids	12
More unsaturated acids	1
Transisomers	32

In our operation the percentage of solid separated from the oil may be approximated from Figure 1.

WINTERIZING

The term winterizing seems to stem from the former practice of allowing an oil to stand and settle in an outside tank during the winter. Mechanical refrigeration is now used. The problem of winterizing is principally a matter of producing crystals of a form that can be separated from the uncrystallized oil. The hydrogenated soybean oil may be considered a viscous medium, and the difficulty of forming crystals from large molecules such as triglycerides in viscous media are well known.

The oil must be cooled slowly to produce filterable crystals. Even under the most favorable conditions the separation of solid and liquid phases will be difficult and incomplete. Because this operation is slow, and poor separations are obtained, the design of the winterizing equipment will be critical in the performance of the plant. Initially, the oil must be heated and held at a temperature that will destroy any crystals or nuclei that may accidentally be present. The oil is then cooled rapidly to 70°F. The cooling rate is reduced, and the oil is cooled to 55°F.

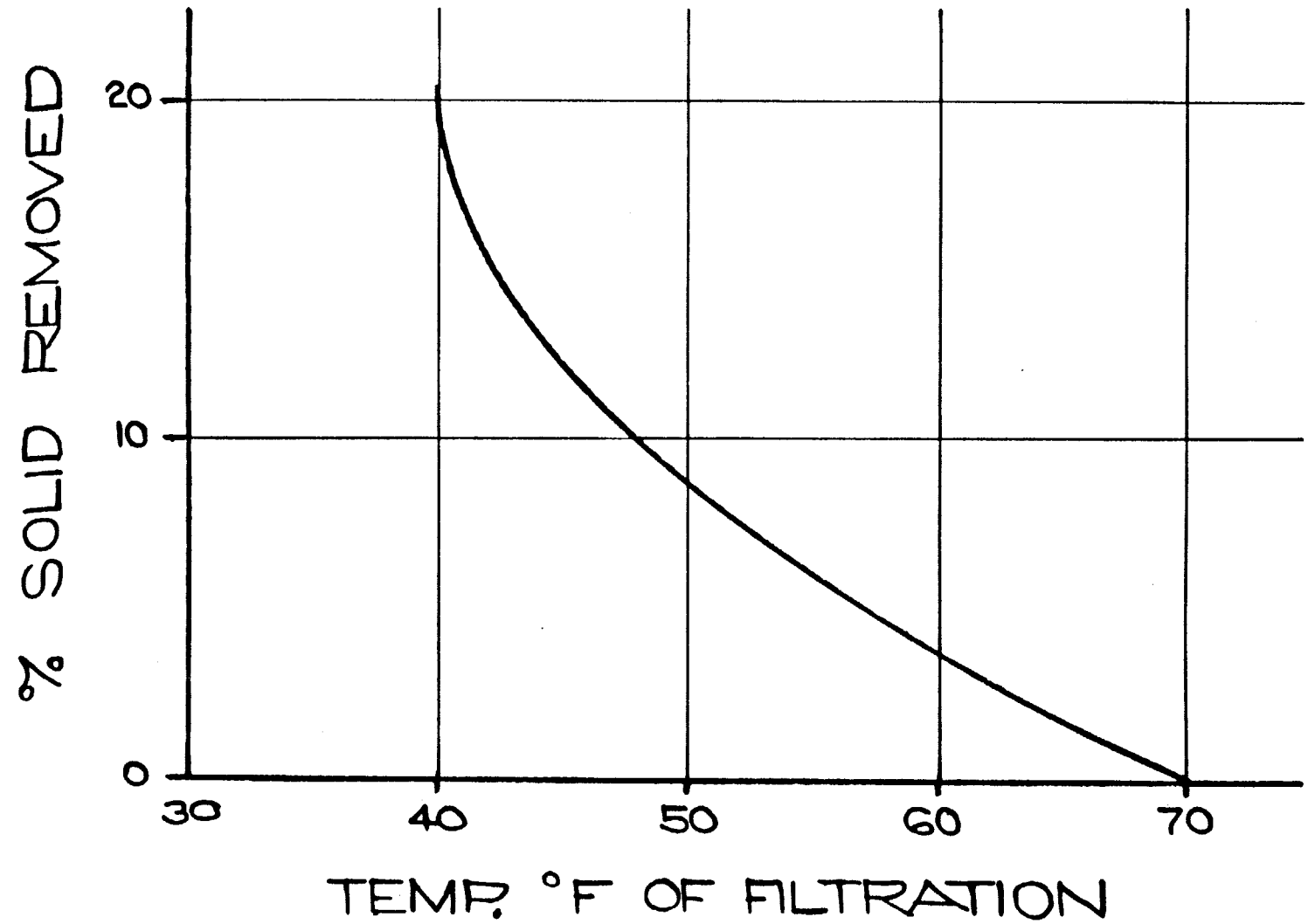

Figure 1

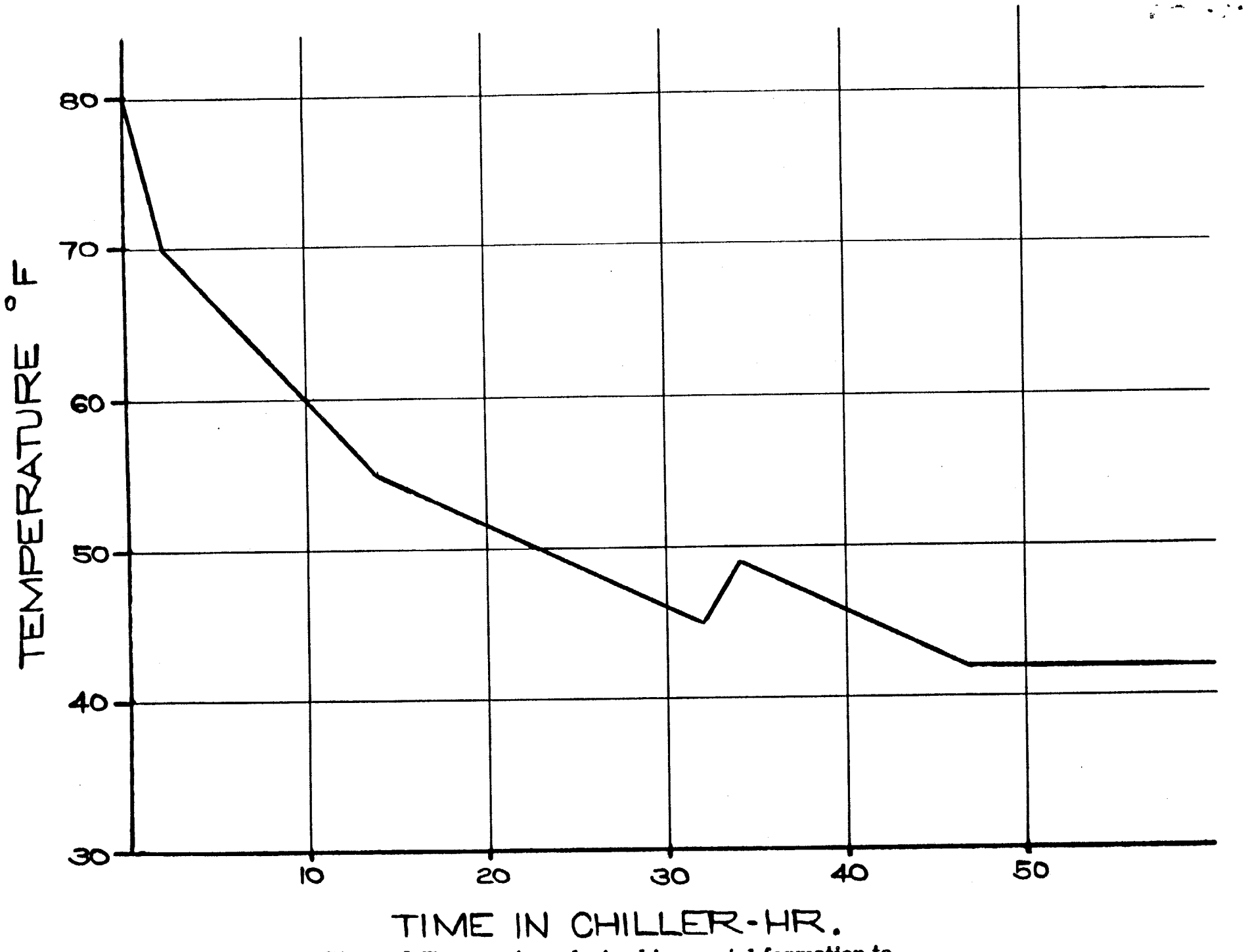

Figure 2 Temperature desired in crystal formation to achieve good filtration.

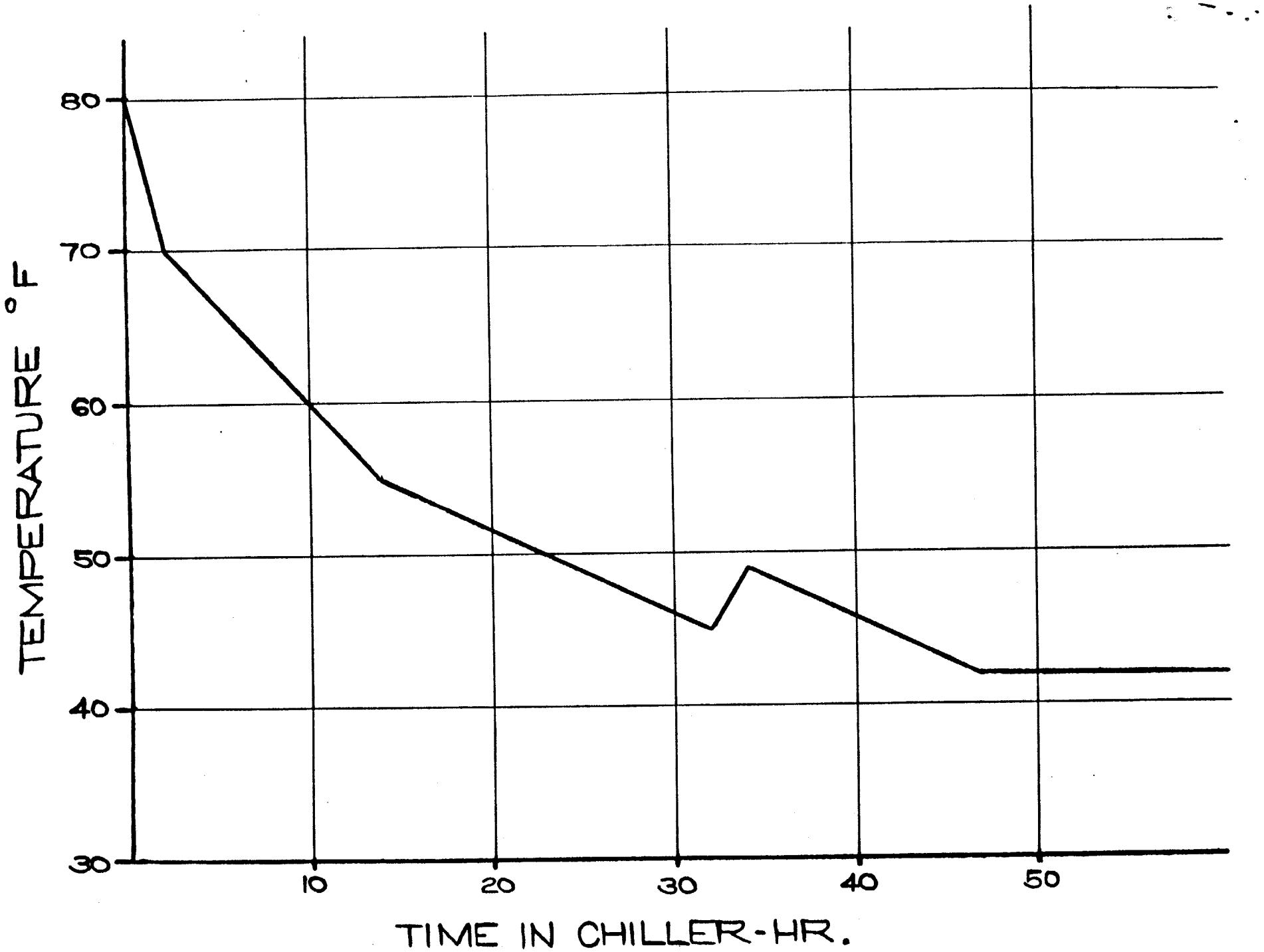

Figure 2 Temperature desired in crystal formation to achieve good filtration.

in about 12 hours. The cooling rate is further reduced, and an additional 18 hours allowed for cooling the oil to 45°F. At this time the rate of crystallization becomes sufficiently rapid to raise the temperature of the oil at a constant refrigeration rate. The temperature will rise 2° to 4° and then drop as before. When it has dropped to 42°F., the batch is held for at least 12 hours. Figure 2 shows this program. Experience has shown that the best crystals are formed when the cooling medium is maintained about 2°F. below the temperature of the oil during the critical cooling period (from 55°F. down).

Conventionally, filtration has been done in plate-and-frame filter presses. A minimum of shear should be exerted on the oil-crystal mixture to prevent disintegration of crystals. Frequently the chilled mass is dropped by gravity into a closed pressure tank, an "egg," from which it is forced through the presses by compressed air. Alternately, a pressure chiller may be used as a tank from which to feed the presses.

Low-pressure filtration, 20 lb./sq. in., with a filter rate of 1 lb. of oil/(hr.) (sq. ft. of filter surface) will separate the crystals from the liquid oil. When the oil has been filtered, the cake may be melted and the filter cleaned by circulating warm water through the filter press.

PHYSICAL PROPERTIES

Physical properties of natural vegetable oils vary somewhat with the composition of the particular sample. For this design we recommend that the following data be used.

	Temperature	Specific heat, B.t.u./(lb.) (°F.)
Specific heat		
Liquid oil	34°F.	0.448
	101°F.	0.469
Solid oil	40°F.	0.51
Heat of fusion	52°cal./g.	
Thermal conductivity (liquid oil)	0.133 Btu/(hr.) (sq. ft.) (°F./ft.)	
Density	Temperature, °F.	gram/milliliter
Liquid oil	40	0.922
	50	0.918
	60	0.915
	70	0.911
	80	0.908
	90	0.904
Solid oil	42.9	0.982
Viscosity	100	30 centistoke
	210	8 centistoke

FURTHER READING

For more information on the processing of edible vegetable oils, you are referred to Swern, Daniel, ed., "Bailey's Industrial Oil and Fat Products," 3 ed., Interscience Publishers, New York (1964).

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