Winter construction

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PREFACE

The problems connected with building during winter months have been a concern of the Division of Building Research since its beginning. This phase of building research is one that Canada has in common with other countries, notably the Scandinavian countries. Much can be learned from their experience.

It is hoped that the translation of this article on winter construction practices in Sweden will be of help to those in Canada concerned with this problem.

The Division of Building Research wishes to thank Mr. H.A.G. Nathan for translating this article.

Ottawa,
November 1955.

Robert F. Legget,
Director.

WINTER CONSTRUCTION

INTRODUCTION

An idle building trade during the winter was formerly taken for granted and considered a natural event everywhere. The entire building activity and thus the building-material industry came to a standstill after October 1st.

There has been a steadily growing trend towards building activity the year round for a number of reasons. As in other key industries, labour within the building trade has become increasingly specialized. During the winter the construction worker today has no longer the same possibilities of switching over to another occupation where he might assert himself in competition. Since numerous mechanical aids are now available to the contractor at the building site, it is only natural that he should be interested in utilizing them economically and thus avoid unproductive idle periods. On the other hand, the situation on the labour market during the past decade made it essential to utilize all the available labour the year round. Last but not least, state control of the building activity was enacted in order to spread work over the whole year by specifying times at which construction is to start, thus counteracting any unequal burden on the labour market*.

Building activity during the winter no longer encounters technical difficulties which cannot be overcome by

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*What winter stoppage means:

For the construction worker	-	seasonal unemployment.
For the contractor	-	unproductive expenses for machinery and administration.
For the property owner	-	loss of rent, which eventually will affect the amount of rent paid by the tenant.

present-day resources, apart from certain types of construction work which should not be carried out in winter, i.e., exterior plastering, exterior painting, exterior paving, levelling and landscaping. However, these types of work may be suspended without any great interruption of the time-table until the weather becomes more favourable and may then be carried out at the best suitable moment, irrespective of the other construction work.

Above all, three factors, i.e., cold weather, snow and darkness, decisively affect winter construction. The manner in which these factors assert themselves is explained in greater detail under the heading "Winter weather conditions in Sweden". In order to counteract these factors a number of different measures must be taken. However, it should be remembered that special measures are costly, especially in a building under construction. The problem facing the contractor when he wants to maintain building activity the year round is as follows.

The costs for winter measures should be balanced in such a way that they leave a margin of profit for the builder and take into account the public interest as well. These measures, which are of a long-term nature, are intended to spread the building activity more evenly, corresponding to the level of occupation in other industries*.

A study of the records is being made in Sweden to determine the extra cost of winter construction. This study is

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*Seasonal unemployment means:

A burden on the labour market, unemployment insurance benefits or compulsory retraining for another occupation during the winter.

Building the year round means:

A more permanent labour force, economic and social security; the demand on the building-material industry and transportation companies is more evenly distributed.

made possible by a grant from the Statens Kommitté för Byggnadsforskning (State Committee for Building Research) and is being conducted by the author. This analysis is based on investigations during the years 1945-52. It is intended to establish, with the aid of this research report, a schedule based on different data obtained from a study of a representative selection of buildings. Furthermore, it is also intended to determine the economic effect of such schedules and fixed times for starting construction work on the building costs for different types of houses.

In order to determine the expense imposed by winter on year round building activity, the fact that weather conditions may be the cause of additional costs during all the four seasons must be taken into account. On the other hand, certain types of work may be facilitated by winter weather conditions, in any case compared with conditions brought about by rain, etc., during the fall.

The present booklet deals in the first place with measures taken during the winter in order to carry out certain types of work which normally cannot be carried out during this season without additional expense. This booklet does not claim to be conclusive but merely reports on practical experience gained and observations made in winter construction. Furthermore its scope does not permit a description of all the machinery for winter construction found on the market. In cases where the trade names of different devices have been given this does not mean the description presents an opinion. It is merely intended to show roughly what may be useful. Data on the capacity and consumption of fuel, etc., have been gathered from the distributors of the devices.

The type of work which increases the cost of construction during the winter is carried out chiefly by unskilled labour and bricklayers. It is reported under the headings:

Foundation work, concreting and cement work, masonry, interior plastering, maintenance of building site, snow removal, etc.*

WINTER WEATHER CONDITIONS IN SWEDEN

Cold weather. Cold weather conditions in different parts of the country bring about different conditions of depth and duration of frost. This decisively affects the planning of foundation work.

According to BABS** "unfrozen ground" is the ground below the surface on which the foundation walls and footings may be erected without danger of freezing. This suggests that the unfrozen ground always is a relative value. Apart from the temperature the following factors affect the freezing of the soil: thickness of the snow cover, duration of the snow period and geological conditions of the soil. Therefore, under exceptionally unfavourable conditions, the numerical data on the unfrozen ground may be very misleading. This may have disastrous consequences. It proved costly to many builders during the cold winters of the last war. The map shown in Fig. 2 has been corrected by taking into account the values for the unfrozen ground during these winters.

The effect of the cold weather on other types of construction work varies. Repeated fluctuations in temperature about 0°C. have an adverse effect on concreting, even if the concrete itself is frost-resistant. Thaws alternating with periods

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*Terminology in the present booklet is identical with that of[4] [cf. list of references on p.49] of the present paper .

**The Building Committee's recommendations for building codes.

of freezing may have a devastating effect on other types of construction work as well. The diagram in Fig. 3 clearly shows how the winter in Stockholm is characterized by incessant changes about the freezing point, i.e., changes about 0°C. In Norrland persistent freezing temperatures may be expected with some degree of certainty and plans can be made accordingly.

Freezing temperatures reduce the capacity of the atmosphere for absorbing moisture, i.e., they increase the relative humidity of the atmosphere. This means that the relative humidity of the atmosphere is higher during the winter than during the summer despite the fact that the absolute moisture content of the atmosphere is lower. Hence, owing to the cold weather during the winter it takes a building longer to dry out (cf. Interior plastering, p.30). However, if the air temperature increases the relative humidity of the atmosphere decreases and the capacity of the atmosphere for absorbing moisture is thus increased. The following example illustrates the importance of the air temperature for the relative humidity of the atmosphere. At a temperature of +20°C. and 100% saturation 1 kgm. of air contains 14 gm. of water. At +55°C. and 100% saturation the same amount of air can absorb 114 gm. of water. This example shows how important heat is in construction work because of the great deal of moisture produced.

In certain respects the persistent freezing temperatures and the more severe frost in Norrland seem to be more or less compensated for by the fact that the atmosphere is drier here than in central and southern Sweden, especially at the west coast. In other words, there is no combination of low temperatures and high humidities of the atmosphere. Therefore, the climate of Norrland is often more favourable for the storage of certain types of building materials, e.g. bricks and lumber.

Snow. Although the problems of snow removal are much greater in Norrland than in central and southern Sweden, the "real" winter in Norrland with the snow cover remaining on the ground for a certain length of time has its advantages for the building activity. Thaw and slush are not encountered to the same extent here. Therefore, it may be expected that the snow becomes packed and forms a better and more permanent roadway.

Darkness. The hours of darkness during the winter in different parts of Sweden can be seen in the diagrams shown in Fig. 6. As the criterion of diffused "daylight", a light intensity of 500 lux has been chosen. It is assumed that this is the minimum amount of light required for carrying on construction work.

How much a person can see at a building site without artificial light does not depend on the diffused daylight alone. The reflecting power of the ground is an important factor and must also be taken into account. The reflecting power, of course, is increased to a great extent by the snow. Therefore, from this point of view snowfalls are advantageous.

It is also important whether the sky is overcast or whether it is hazy or clear. Fig. 6 gives the hours of sunshine per month during the years 1951--52, i.e., the same period as in the diagram for temperature and precipitation (Fig. 3).

Length of Winter

The need for winter measures for different types of construction work varies with the climatic conditions of different parts of Sweden. If these measures depended only on temperatures and snowfalls, the actual beginning of winter would still be dubious in many instances. In the introduction of this paper the winter was defined as the time during which special measures must be taken at a building site. It is clear that winter thus defined does not start simultaneously for all types of construction work.

For example, concreting cannot be carried out without special measures at temperatures below +50°C. As Fig. 3 shows, an average temperature of more than +5°C. cannot be expected in the Stockholm district between November 1st and April 15th*. This means that what may be called in this connection "winter" as far as concreting is concerned corresponds to the period between November 1st and April 15th in central Sweden.

Regarding interior plastering the winter period is roughly the same as in the case of concreting.

The heating of the shacks comes under maintenance of building site. In this case winter begins earlier. In general, the heating of the shacks begins around October 1st and does not cease before some time around the end of April. Therefore, winter as far as the maintenance of the building site is concerned may be considered a specified period (October 1st to April 30th)**.

FOUNDATION WORK

Everyone in the building trade knows that it is most advantageous to begin building sufficiently early to complete the foundation work before the frost sets in. If for one reason or another this should be impossible, much can be gained by covering the part of the ground to be excavated, thus protecting it against frost. The material for covering the excavation costs very little compared with what it would cost to excavate frozen soil.

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* One day mild and a few degrees of frost the next is not unusual for Stockholm.

**In order to avoid unpleasant and sometimes costly surprises the changes in the weather must be taken into account.

For large and medium-size buildings the excavation for the basement is generally made by an excavator. A strong excavator works right through a frozen crust 25 or 30 cm. thick. This means that the ground should be protected by a cover if the digging of the excavation is planned at a time when the frost has penetrated to a great depth, but that a cover is not required for mild frost or for short delays in the excavation work.

The foundation should be back filled up to the ground walls as soon as possible. Frequently the material required for back filling the foundation is left lying at the building site and freezes. This means it must be left that way and may thus interfere with the progress practically the entire time a building is under construction. How much trouble this may cause need not be emphasized. Therefore, the material for back filling the foundation must be removed at all cost before it freezes. If the material freezes and is then removed, it may cost ten times as much.

Protective Cover for the Ground

A layer of straw, or similar insulating material, approximately 30 cm. thick, is used to cover the ground if frost is expected. The straw may be bundled; bundles of straw may also be used for the protection of concrete. Experience in Denmark shows that straw can keep the ground free from frost down to temperatures of approximately -10°C.

Excavations in Frozen Soil

Frost interferes above all with excavations dug by hand, such as trenches, excavations for foundations, trenches for footings, etc.

It is often extremely difficult to protect the ground for trench work with a cover. It may even be advantageous if vertical surfaces freeze slightly. This decreases the danger of collapse and the work can be carried out more easily in trenches. Trenches for footings can be adequately protected by covering them during the night with straw, tarpaulins, etc.

Soil excavated by hand and used for refilling, is not covered, as a rule, and usually freezes. The following methods may be applied to such frozen soil:

(a) The frozen crust is broken up with the aid of wedges. In case of moderate frost a pick axe or an iron bar may be used.

(b) The frozen crust is broken up with a pneumatic spade, a very effective device for frozen soil. However, only in the case of a large building would the purchase or rent of a compressor be justified.

(c) The frozen crust is blasted; however, for the sake of safety this can only be recommended when the building is at sufficient distance from other buildings, or else only small quantities of explosives should be used.

(d) The frozen crust is defrosted. In Denmark tests were made in this respect with a hot-water stream under a layer of straw, chemical agents, etc. But none of these methods are really recommended by Danish constructors. It is unlikely that these methods have ever been tried in Sweden.

Protection of Temporary Water Systems

Temporary water system must be prevented from freezing so that no valuable time is wasted with thawing. Therefore, it is of the utmost importance that all water conduits are emptied when the workmen leave the building site in the afternoon*.

*It may cause a great deal of inconvenience in a building under construction if the temporary water systems are allowed to freeze. Burst pipes are expensive to repair and many valuable working hours are lost if conduits must be defrosted.

Frequently the water system is protected by installing the conduits in double wooden casings filled with fresh horse manure and insulated with glass wool. The pipe lines also are insulated.

Another method may also be used to protect the temporary water system against frost, i.e., by conducting an electric current of low voltage through the pipe itself or through an uninsulated cable within the pipe. The same current as drawn by a 40-watt lamp is effective.

CONCRETING AND CEMENT WORK

The rate of chemical reaction decreases as the temperature decreases. This also applies to the reaction of cement and water, as shown in detail in Fig. 11.

If the temperature of concrete drops below the freezing point during pouring so that water contained in the concrete freezes, the concrete cannot set. At external temperatures between ±0°C. and +5°C. concrete sets very slowly. Even at +5°C. the time required for setting is approximately four times that at +20°C. In other words, when the external temperature drops below +5°C. the temperature passes the boundary below which special measures must be taken for technical reasons if concrete is poured outdoors .

After taking various protective measures concrete can be poured at temperatures right down to -15°C. However, opinions as to what is the lowest possible external temperature for pouring concrete differ. In Norrland it is unlikely that a contractor will pour concrete at a temperature of -20°C. Even in

*An external temperature of +5°C. is the "winter boundary" for concreting. As far as concreting is concerned, winter in central Sweden lasts from November 1st to April 15th.

the recommendations for concreting during the winter, issued by the Swedish Cement Association(10), and in the instructions concerning a concreting technique, published by the Swedish Research Institute for Cement and Concrete(8), the lower limit for pouring concrete is set at an air temperature of -20°C. However, it is a known fact that contractors in Stockholm normally do not pour concrete at these low temperatures*.

The diagram in Fig. 11 shows how the air temperature affects the hardening of concrete; the hardening of concrete of a given composition at +20°C. is compared with the hardening of concrete of the same composition at lower temperatures. At +20°C. the concrete attains a strength which permits loading with 200 - 250 kgm./sq.cm. 28 days after pouring. This strength is referred to below as "28-day strength" and denotes a standard increase in strength for ordinary concrete.

For example, at +5°C. the strength after 28 days is only from 60 to 70% of the 28-day strength at +20°C. This is the same strength which concrete attains at +20°C. after only 7 days. This strength, i.e., 60 to 70% of 28-day strength, is considered the lowest strength which concrete may have before forms can be removed, e.g. for framing joists(6). Hence at an external temperature of +5°C. it takes 28 days before the forms can be removed from concrete unless the temperature of the concrete is increased by various means.

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*In order to increase the temperature of the material for pouring, it is more effective to heat the water rather than the other ingredients of the concrete, particularly since the specific heat of water is 1.0 while that of cement and large aggregate is only 0.2. Furthermore, the temperature of water can be controlled more easily. A temperature of +60°C. is just right and a temperature exceeding +70°C. too high. At moderately low external temperatures heating the water alone is sufficient and the required temperature of the material for pouring is obtained nevertheless.

The strength increases rapidly during the first seven days. At a temperature of +5°C. the concrete has attained from 20 to 30% of the 28-day strength as early as three days after pouring. This strength is adequate to prevent freezing in the normal case, i.e., the concrete is frost-resistant. (According to American investigations resistance to frost requires a strength of 35 kgm./sq.cm.). If the concrete freezes the water, which normally would have been used in the process of hydration or would have evaporated, freezes. If the temperature during the first three days is increased to +18 or +20°C. the concrete attains approximately 45% of the 28-day strength and the resistance to frost is fully assured. Therefore, the first days after pouring are crucial and are here called the critical setting period. The following are the requirements for pouring concrete during the winter:

1. The material for pouring must be kept at a suitable temperature.
2. The temperature of the freshly poured concrete must not decrease below a certain minimum during the critical setting period.
3. The time for removing the forms must be adapted to the cold weather conditions.

These requirements are met by taking the following measures.

<u>Requirement 1:</u>

(a) Protection of the large aggregate
(b) Protection of the forms and reinforcements
(c) Heating the sand and water

<u>Requirement 2:</u>

(a) Selecting the proper type of cement
(b) Chemical addition agent
(c) Suitable water-cement ratio
(d) Protection of the concrete during the setting time
(e) Heating the concrete during the setting time

Requirement 3:
(a) Hardness test
(b) Temperature observations

1. <u>The material for pouring is kept at a suitable temperature.</u>

(a) Aggregate is usually protected by covering the piles of sand and coarse gravel with tarpaulins, since this material readily freezes together and must then be separated by pick axe*. This slows down the work unnecessarily.

(b) As a rule, forms and reinforcement are also protected by tarpaulins. Sometimes the area to be covered is so large that the use of tarpaulins is too time-consuming and thus uneconomic. Steam is increasingly used for removing snow and ice from the reinforcement rods and forms, particularly in the case of large buildings (cf. p.37).

(c) Today sand and water are chiefly heated by steam. Boiler plants are described in greater detail on pp.17-19.

The sand, not the gravel, is heated as indicated below. The ready-mixed concrete immediately begins to generate heat of its own. Too high a temperature may result in early evaporation of the water, causing initial set during transportation to the site of pouring. Therefore, the temperature of the material to be poured must not exceed +20 to +30°C.** If the coarse gravel is not heated this has an equalizing effect on the temperature of the material in the mixed concrete. However, if

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* Tarpaulins may be rented at relatively low cost, at least compared with what it would cost to work through the snow if a protective cover is not used. It seldom pays to economize on tarpaulins.

**The upper temperature limit of concrete must be watched. It would be safest not to let it exceed +30°C.

the coarse gravel is heated, not only is the equalizing effect eliminated, but the subsequent shrinkage of the aggregate may result in the loosening of individual stones in the concrete like a hazel nut in the shell. The sand should not be heated too much; this is important.

For heating the sand with steam, perforated iron pipes and steam jets are used, which are stuck into the sand heap in order to heat it directly. The steam jet is connected to the boiler plant of the concreting installation by hoses. Of course, only the amount of sand required for pouring should be covered with tarpaulins in order to retain the heat.

Other more or less primitive heating devices are still found in the sand piles in buildings of all descriptions. For example, it may be mentioned that a curved iron plate is placed into the sand pile and heated in the same way as an old-fashioned baking oven. Special wood stoves of cast iron, so-called sand braziers, are frequently used. If the sand is heated in this way it involves the risk of "burning the sand".

Heating the water greatly affects the temperature of the concrete. Since the specific heat of water is high compared with that of the other materials making up the concrete, it is clear that not only does the water require a great heat input but at the same time it supplies most of the heat to the concrete mixture. Furthermore, the water must not be heated excessively, since too high a water temperature may bring about premature setting of the cement.

The Swedish Cement Association recommends the following maximum temperatures for the heating of both sand and water:

+60°C. for the use of standard cement.
+35°C. for the use of quick-setting cement.

As mentioned above, the temperature of the ready-mixed concrete should not exceed +20°C. to +30°C. Such high temperatures may be applied to the various materials mentioned above, because the material cools sufficiently on the way from the storage plant to the mixer.

It has become evident that all sorts of boiler plants are used for heating the material making up the concrete. Sand braziers are disappearing fast. Two main types of boilers are in use today: low-pressure boilers and high-pressure boilers. In the past, low-pressure boilers were most commonly used in central Sweden, but today high-pressure boilers are more frequently used. In Norrland, with its more severe climate, high-pressure boilers are exclusively used for large-size buildings under construction.

Modern low-pressure boilers are quickly fired and can be heated with waste wood, sawdust, peat or other relatively cheap fuel. According to commercial advertising the boilers are left at full steam for 7 minutes, the steam capacity being from 160 to 200 kgm./hr. These boilers have an entirely automatic water feed and the fire box is surrounded by water, which prevents overheating of the sheet metal.

As a rule, the heat generated by low-pressure boilers is not sufficient to heat both the gravel and the water as well as simultaneously to thaw the ice and snow in the forms and reinforcements. Therefore, low-pressure boilers are frequently provided with a special water heater.

As a rule such a water heater is designed in approximately the following way. The water is conducted from the temporary water system through a coiled pipe (usually of copper), which ends up in a tank. The tank may vary from an ordinary brick-encased sheet-metal water barrel, which is fired directly, to modern water heaters with double jackets and convenient firing equipment. The tank is filled with water and fired, therby heating the water in the coiled pipe within the tank. Hence the water for the concrete is heated in some sort of water bath. The coiled pipe has a drain at the concrete mixer.

Some of the modern low-pressure boilers, for example, the so-called VEA boiler, and certain types of the Osby boiler have built-in filament batteries for heating the water, thus making separate water heaters unnecessary.

High-pressure boilers. The most essential difference between low-pressure boilers and high-pressure boilers, of course, is the capacity of generating steam. High-pressure boilers have a steam-pressure of 4 to 12 kgm./sq.cm. Wood, coal, oil and waste wood may be used as fuel. Because of the greater capacity of generating steam the water tank need not be heated directly. As is evident from Fig. 19, quite frequently old mobile steam generators are used as high-pressure boilers*.

Since high-pressure boilers are not easy to install, they should preferably be used only for large construction projects so that they do not have to be moved for some time. The easily damaged and expensive fittings must be protected and it is often necessary to house the entire installation in a shed. New types of high-pressure boilers are being tested at present.

The costs for installing and operating a steam boiler are decisive economic factors. The extent of the construction and the weather conditions at the building site determine the choice of the installation and the outlay for it. The type of

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*Mobile steam generators have become a common sight in construction today. Apparently there are no high-pressure boilers of modern design which can compare with the mobile steam generators in efficiency.

fuel does not affect the operating costs as much as the cost of labour. The costs for operating automatically fired installations should be lower than those for manually fired installations. Although the fuel costs for an oil-fired installation are high, the cost of labour is correspondingly lower.

Firing with waste wood may increase the cost of labour considerably. Frequently one labourer is needed for collecting and sorting the wood. An easily manageable crosscut saw may possibly reduce the cost of labour and should always be available, at least for large building projects.

High-pressure boiler plants may be operated by unskilled labourers as firemen, who handle both the boilers and the steam jets. This usually fully occupies one man in a large building project.

2. <u>The temperature of the freshly poured concrete must not decrease below a certain minimum during the critical setting period</u>.

The length of the critical setting period depends on the selection of the proper cement type, the chemical addition agent and the water-cement ratio. The freshly poured concrete must be protected in order to retain the heat of reaction and possibly the heat supplied.

(a) <u>Selection of proper cement type</u>

No data are given here concerning the pouring of concrete treated with E cement since the latter is not very suitable for concreting during the winter on account of its composition.

If the concrete contains standard cement, the raw material must be kept heated during the pouring and the concrete should be protected and must possibly be heated during the critical setting period. If the amount of cement is increased the concrete sets more rapidly.

Quick-setting cement generates much more heat than standard cement during the setting time*. However, the raw material for the concrete must be heated in the usual manner during the pouring, but need not be covered or heated subsequently.

If quick-setting cement is used, the upper temperature limit for the material for pouring is considerably lower than that in the case of standard cement. This must be taken into account when the water and gravel are heated. At least 350 kgm. of quick-setting cement per cu.m. of concrete should be used in the mixture. The poured concrete can be loaded without danger, i.e., the forms may be disassembled after 3 or 4 days. During the critical situation in the building industry quick-setting cement was a scarce item because of supply difficulties. Furthermore, quick-setting cement costs from 50 to 70% more than standard cement. Therefore, as a rule, quick-setting cement is used only for small jobs and rush work.

It is very important to avoid the use of old cement (and possibly cement containing humus impurities) during the winter. Cement should not be stored for any length of time under freezing conditions and not more than is actually required for pouring should be made.

(b) Chemical addition agents

Chemical addition agents are used during the winter in order to hasten the setting of the concrete. As a rule calcium chloride ($CaCl_2$), which reduces the freezing point of the concrete somewhat, is added. However, the amount added is not large enough that the usual protective measures may be dispensed with.

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*3-day "quick-setting concrete" = 7-day standard concrete; 7-day "quick-setting concrete" = 28-day standard concrete.

Concrete containing $CaCl_2$ freezes at approximately -5°C. and is more readily workable. This may be utilized for reducing the water content of the concrete. However, these two properties are only of secondary importance. The fact that $CaCl_2$ hastens the setting of the concrete is of prime importance. Of course, care should be taken that the concrete does not begin to set in the concrete mixer or on the way to the job.

As a rule, 1% of the weight of the cement is a suitable amount for the addition agent. If the external temperature is expected to drop below -5°C. directly after the pouring, the amount should be increased slightly, but not to more than 2% of the weight of the cement. Furthermore, the concrete must be covered as rapidly as possible after the pouring.

According to the Swedish Cement Association, the strength of the concrete increases in the following manner when the amount of calcium chloride added is 2%. "The strength of a 2-day sample increases approximately 50%, that of a 7-day sample approximately 25% and that of a 28-day sample approximately 10% compared with a corresponding concrete with no chemical agent added. However, the final strength will be approximately the same in both cases"(10). The temperature of a poured concrete with a chemical agent added should not decrease below +10°C. during the first day and not below +3°C. during the third day.

(c) <u>Suitable water-cement ratio</u>

The danger of the concrete freezing during the first critical setting period diminishes if the water-cement ratio is kept as low as possible. This is usually taken into account today and everything possible is done to keep this ratio down.

Concrete vibrators are important in this connection, since they permit the use of a drier concrete*.

(d) During the setting time the concrete is protected by covering it with a heat-insulating material. The earlier the fresh concrete is insulated, the better will be its quality. Paper bags placed directly on the concrete may help to reduce heat losses (due to convection and radiation). In other respects paper bags are useless as insulating material. The insulation must be tightly packed. Gaps in the forms are often excellent for protecting the concrete. For external insulation the gaps may be covered with tarpaulins. The most effective heat-insulating materials are straw, straw mats, glass wool mats, cement bags filled with cutter shavings, etc.

(e) Concrete must be heated during setting time if the external temperature drops below -5°C., or if the concrete structure is particularly thin. In such cases the heat is applied under concrete slabs, not only to prevent the concrete itself from freezing but also to facilitate the loosening of frozen forms**.

The temperature of the concrete should be checked preferably with thermometers inserted in the freshly poured material***. Small holes of varying depth may be left in the

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* The vibrator plays an important role during the winter, particularly when relatively thin wall structures are poured. This permits the use of a drier concrete and decreases the danger that the concrete freezes before it becomes frost-resistant.

** Avoid overheating under freshly poured concrete slab. Abrupt changes of temperature or repeated changes about 0°C. may be detrimental to the concrete, even if it is frost-resistant.

*** Thermometers are essential during the winter. A maximum-minimum thermometer is needed for measuring the external temperature and there should be special thermometers for the concrete.

concrete for this purpose (cf. Fig.25). It would be ideal if the temperature could be prevented from ever dropping below +7°C. during the setting time. This often requires three days of heating. After this time the cement generates sufficient heat of its own to maintain the temperature.

If too much heat is applied under a freshly poured concrete slab for 3 days and the concrete is then allowed to set without protective measures at external temperatures below 0°C., the concrete seems to be detrimentally affected by the abrupt change in temperature, even if the concrete has become frost-resistant. Furthermore, the water in the concrete evaporates too rapidly if too much heat is applied. Therefore, moderate heat should be applied either under or within the freshly poured concrete.

On the whole, the same types of heating device are used for concrete as for the drying of interior plaster (cf. pp. 30-35) and are placed under the freshly poured concrete. Holes in the brickwork are covered with makeshift arrangements such as cardboard, wood, etc.

Coke braziers are the most common heating devices (cf. Fig. 30 and p.32).

Wood stoves are described in greater detail on p.33.

Boiler plants are occasionally used for heating concrete during the setting time by conveying the steam in ribbed radiating pipes, which are mounted under the freshly poured slab. However, this would require special connection pipes thus making the installation a large undertaking. Therefore, the expense for heating the concrete in this way is out of all proportion as far as an ordinary dwelling is concerned. If the slab has a very large surface, as in the case of schools, hospitals or commercial buildings, the installation of such a plant may be justified.

A kerosene-heated hot-air unit of the "Lun-tork" type (Fig. 24) has been on the market for the past few years.

Hot-air fans are sometimes used, but mostly for drying the plaster (cf. pp.30-35).

3. Time for removing the forms must be adapted to the cold-weather conditions.

The time for removing the forms is determined by the strength which the concrete must have in order to support itself and possibly an additional load. This time is affected by the number of cold days.

(a) Hardness tests are made in selected cases. The sample is poured simultaneously with the concrete construction and exposed to the same changes of temperature as the latter.

(b) Temperature observations include the checking of the temperature of both the air and the concrete. In view of the fact that the forms are generally not removed before seven days after the pouring, the days with an air temperature lower than 0°C. must not be counted. A diagram showing the increase in strength of the concrete at various temperatures should be available at the building site (cf. Fig. 11).

General Rules for Pouring Concrete During the Winter

At the moment of pouring, the temperature of the ready-mixed concrete is maintained at a minimum of +5°C. in the slab and ground walls and at +10°C. in thinner building parts, such as walls.

As soon as the freshly poured concrete begins to generate heat, its temperature should be maintained between +15 and +20°C. during the three critical days. The concrete thus attains the degree of setting required to become frost-resistant.

The water-cement ratio of the concrete must be kept as low as possible in order to decrease the danger of cracking and freezing.

If the amount of cement is increased, the time required for setting is decreased and thus the danger of freezing is reduced.

If quick-setting cement is used, the material must be heated and the freshly poured concrete covered, but the concrete need not be heated during the setting time.

The time which the form for the concrete must be left in place depends on the number of cold days*. The reader is referred to pages 26 and 27, where a summary is given of the measures which should be taken at different air temperatures within the first week after the pouring (according to H. Röhfors[6]). Of course, it is assumed that the temperature never drops below the lowest temperature of the intervals given. These measures are intended to assure that the building activity is interrupted as little as possible. This is a minimum of all-round protective measures that may be recommended.

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*A diagram showing the increases in strength of the concrete at different temperatures should always be available at the building site.

At temperatures	
+5° to ±0°C.	When no $CaCl_2$ is added the water should be heated. When $CaCl_2$ is added no special measures are required, but the forms should be removed after approximately the same time as during the summer.
±0° to -5°C.	The water should be heated and preferably $CaCl_2$ added. If $CaCl_2$ is added, the concrete may be poured without heating the water. The sand should be heated and frozen lumps thawed. The freshly poured concrete should be covered during the first night with tarpaulins or cardboard on a framework, or at least with cement bags.
-5° to -10°C.	The water should be heated and preferably $CaCl_2$ added. The sand should be heated and frozen lumps thawed. The freshly poured concrete should be insulated for three days with straw, straw mats or similar insulating materials. Gaps in the storey below should be covered and the temperature in the room under the concrete slab should be kept above 0°C. for three days.
Lower than -10°C.	It would be preferable to postpone the pouring of the concrete, but if the concrete must be poured the same measures as at temperatures between -5° and -10°C. should be taken. The insulation should not be removed until the temperature stays above -10°C.

The measures to be taken at air temperatures below 0°C. are only for preventing the concrete from freezing.

The water used in cement work during the winter must be heated as for concrete. Special measures for heating the cement during the setting time are usually not required, since the building is roofed when cement work is carried out. Furthermore, by this time the other construction work has advanced to a point where the drying and heating devices installed prevent the temperature within the building from dropping sufficiently to affect the cement work detrimentally. However, should it become necessary, measures to protect the cement against frost must be taken as in the case of concrete.

MASONRY

In order to build masonry during the winter it is essential that the bricks be kept absolutely dry. Bricks must be protected against precipitation irrespective of the season. Furthermore, during the winter the mortar must be heated. Taking these measures, outdoor building can be carried out at temperatures down to -10°C.

Jointing of façade bricks during the winter requires special care. However, if jointing is postponed to the spring the façade should be protected, involving additional expense. Jointing might just as well be carried out simultaneously with the laying of the bricks, provided, of course, that the bricks are sufficiently dry to absorb the water in the mortar. If a building is exposed to the weather, particularly to the wind, or if a building is high, jointing becomes more hazardous. If jointing is carried out in cold weather (and this is frequently done) the façade should be covered with tarpaulins, etc.

Heated mortar may be obtained at a small additional cost, at least in larger communities. The mortar must be kept heated while the work is going on and this can be done in three different ways: (a) by insulating the mortar bed, (b) by heating the mortar, and (c) by mixing the mortar with hot water.

(a) The mortar bed may be insulated by putting fresh horse manure around it. Various types of insulating mats, such as glass wool mats, straw mats, etc., may also be used. In addition to the insulation the bed is often covered over, usually with tarpaulins or shutters. The bed should be kept covered as much as possible, even while work is in progress.

(b) There are various ways of heating the mortar. A strong light or an electric element, placed under the protective cover, may be used. Even a heating coil from a boiler plant may be placed under the bed (cf. Fig. 19).

(c) Hot water is the most effective means of heating the mortar while the latter is mixed. Water produces five times as much heat per unit weight as the other components of the mortar. Hot water may be obtained either from the boiler plant of the concreting installation or directly from a water heater.

The mortar must be kept soft by mechanical stirring (cf. Fig. 27). This is more important during the winter than during the other seasons.

The mortar bed should preferably be kept empty after working hours. Needless to say, a lot can be saved if the consumption of mortar during the winter can be calculated directly, because the protection of mortar against frost during the night increases the total costs unnecessarily.

The mortar may be insulated during the night by building the bed in a shed. The latter should be provided with an opening so that the mortar can be dumped directly from trucks over the bed, which usually can be locked and may possibly be insulated externally. The bed may also be placed on a thick bed of sand, which is heated by steam coils from the boiler plant.

Mortar tubs of wood are preferable during the winter. Tin vessels are unsuitable, since the water freezes more easily in them.

The masonry in a building under construction must be protected against precipitation in order to avoid damage due to frost and to facilitate drying. Of course, when the work is interrupted the masonry must be covered over.

Buildings which happen to be exposed to intense sunshine on one or two sides should be protected with tarpaulins during the winter while the masonry is being constructed. Otherwise the mortar might shrink more rapidly in the part exposed to the sun than in the shaded part, resulting in crooked walls.

The above applies not only to mortar but also to clinker masonry, as well as conrete-block walls and tiled walls, although the amount of mortar per cu.m. of masonry in the last two categories is smaller.

A fairly new technique of constructing walls which seems to be suitable for winter construction is applied in the so-called parallel-block masonry. This requires a special tool which almost resembles an iron grate with a container for the mortar. The mortar is distributed through the grate in the joints in parallel strings so that air ducts remain open as vertical sections throughout the entire wall. The joint thus has the same heat-insulating properties as a perforated block and the mortar consumption is negligible. Cement mortar is used for building with parallel blocks. In order to harden, the cement mortar must absorb the water which it previously emitted to the wall block. Along with the negligible consumption of mortar, this should have a favourable effect on the drying.

INTERIOR PLASTER WORK

Interior plastering during the winter is made especially difficult by the fact that the moisture must be eliminated. To use a popular expression, there are two "sorts" of moisture: water contained in the mortar and water which forms in the process of carbonization.

Carbonization means that the $Ca(OH)_2$ combines with CO_2 contained in the atmosphere and forms $CaCO_3$ and H_2O. In order to show how much water forms during carbonization an example is given, assuming that sand-lime mortar is used. This is composed of 1 kgm. of lime + 9 kgm. of sand + 2.2 kgm. of water = 12.2 kgm. mortar. The lime consists of 90% of $Ca(OH)_2$ = 0.9 kgm. The carbonization has the following formula:

Reaction: $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$.

Molecular weight: $74.1 + 44 \rightarrow 100.1 + 18$.

If it is assumed that the carbonization is complete the amount of water produced is $\frac{18}{74.1} \times 0.9$ kgm. = 0.22 kgm. Complete carbonization requires a long time and it is reasonable to assume that only one-tenth of the lime carbonizes during the time a building is under construction. Hence in the above example only 0.022 kgm. of water is given off, i.e., only 1% of the water (2.2 kgm.) which the mortar was assumed to contain initially and most of which must be removed before the building is occupied.

This shows that the carbonization is only of secondary importance in the drying of the plaster. Therefore, the supply of CO_2 is not important either and should have no bearing on the selection of the drying system. The removal of the moisture is of prime importance. Cold air absorbs a much smaller amount of water than warm air (cf. p.7)*. The moisture-absorbing power of the air may be increased by heating it; the ability to remove moisture is increased by frequent changes of air. Therefore, heat and changes of air are of prime importance in the drying of plaster.

The measures which are taken during the winter while interior plaster work is carried on are intended:

(1) to protect and heat the plaster itself and
(2) to provide protection and heat during the setting time of the plaster.

(1) <u>Protection and heat for the plaster itself</u>

In larger communities, heated finishing mortar, like mortar for jointing, is delivered to the building site at a small additional cost. In order to protect the mortar bed and to heat the mortar, the same methods are applied here as in the case of mortar for jointing (cf. p.28).

(2) <u>Protection and heat during the setting time of the plaster</u>.

Before the interior plastering begins protection must be provided (a) by casings, and (b) by installing devices for drying the plaster before the setting process begins.

(a) Casings must be used to prevent the escape of heat produced by the drying devices. The window openings and

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*At temperatures between +40° and +60°C. air can absorb eight times as much moisture as at room temperature. Therefore, the temperature should be kept high near newly plastered surfaces.

door openings must be filled up again*. Of course, it would be simpler to install all the windows before the plastering begins. Many builders are reluctant to do this because of the additional expense for repairing glass, and because it may be difficult to clean the glass after the plaster work is finished. Scratching the window panes by the finishing mortar may easily be prevented by protecting the glass with a plastic film.

Sacking on wooden frames is chiefly used for covering windows. However, these frames cannot be interchanged from one building to another unless the windows are of the same size. Therefore, blinds of sacking would be more advantageous. They can be interchanged from one building to another at negligible cost and are independent of the size of the window opening. Wood fibreboard, and even cardboard, are used occasionally.

(b) The plaster is dried either by the permanent heating plant of a building or by different temporary heating devices, such as coke braziers, wood stoves, forced hot-air heaters and kerosene driers.

The permanent heating plant of a building should be used as much as possible, provided it is already in operation. However, its effect is not adequate for drying the plaster within a reasonable time**. There are all sorts of special drying devices on the market.

Coke braziers are easy to move and require little space, but good ventilation is essential in order to reduce the

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* It would be expedient if the window frames with panes are inserted as soon as the shell has been completed. They should be protected with plastic films, etc., against damage caused by the finishing mortar.

**The areas beneath windows are plastered as soon as possible, in order to install the radiators. The permanent heating plant thus complements the other drying devices.

formation of carbon monoxide. Because of the danger of carbon monoxide poisoning, the coke braziers are usually not lighted until the end of the day when the workmen leave the building. During the night, two men on shift must attend to the coke braziers. This, of course, means an increase in the overall costs. Where coke braziers are employed, work must be interrupted, thus making it more difficult to organize the work properly. A coke brazier near an encased window is shown in Fig.30.

Because of the difficulty of obtaining coke during and immediately after the Second World War coke braziers were used instead of wood stoves. However, these have disadvantages since the combustion gases must be conducted from the building through a flue, which may be stuck through the window openings, etc. As a safety measure the stoves are mounted on an iron plate, which rests on bricks. This type of stove is clumsy and very bulky, and is not as effective as the coke brazier. Furthermore it is more expensive in operation and the plaster takes longer to dry, thus increasing the costs.

Hot-air fans are some sort of hot-air heaters provided with blowers. The hot air emitted by them does not produce the heat required for drying the plaster entirely. The fans are usually mounted in the hall and heat the air flowing in, thus keeping the hall free from frost. If a house is heated with the aid of blowers, the pressure increases above atmospheric, with the result that the moist air is forced out through vents, through the sacking in the casings or through leaks in the windows.

In the past hot-air blowers were usually fired with wood. This type of hot-air blower requires a great deal of attention and thus increases the costs. Oil-heated hot-air blowers have come into use in recent years. They require less attention and may be kept going during the night without special care. On the whole, the oil unit operates like that in an ordinary oil-heating plant. In the combustion chamber the atomized oil is mixed with primary air from a blower. The air-oil mixture is ignited while oil pressure and air volume are adjusted for complete combustion. The flue gases thus obtained are mixed with the secondary air, which is admitted through special apertures in the jacket. This air is preheated around the combustion chamber. The hot air-gas mixture is then forced through the outlet of the unit with the aid of the blower and may be distributed through the building by a special system of pipes. Some of the smaller types of oil-heated hot-air blowers are on wheels for easy transport.

Hot-air blowers produce flue gases containing carbon dioxide. However, the amounts of carbon monoxide emitted by them are so small that they do not interfere with work in the vicinity of the blower, provided, of course, that the labourers can endure the great heat produced by the blower. The blowers do not throw off soot either. This is an advantage when the sealer coat is drying. Installation and maintenance of the hot-air fans are relatively inexpensive. Different types of hot-air fans are shown in Figs. 32 and 34.

A novel device for drying a building is the automatic oil-fired drier with high-pressure nozzle. This drier differs from the other hot-air fans above all by the fact that the flue gas is separated from the hot air. This means that the hot air may be utilized while the flue gases are diverted in order to dry rooms which cannot be damaged by the carbon monoxide.

Kerosene-heated driers are increasingly being used in the building trade for drying plaster, especially in small rooms and in rooms where it is difficult to handle other devices. The heat produced by these driers is not as intense as that produced by coke braziers. Therefore, they are usually used in combination. Kerosene-heated driers are very suitable for drying plaster a second time when an even, but not too high, temperature is required (cf. Fig. 24 showing the "Lun-tork").

MAINTENANCE OF BUILDING SITE

By "maintenance of building site" is meant the maintenance of the shacks for the labourers and management of work. The measures taken during the winter in this respect chiefly refer to the heating of the shacks. The best results will be obtained, of course, if the shacks are well insulated. This is frequently the case today. The shacks may be heated by various means, i.e., by wood stoves, electric heaters, kerosene stoves, hot-air heaters and, in exceptional cases, by central heating from the boiler plant. The shacks must be heated by 7.00 a.m. when the work begins and should be kept warm during the day when the labourers use the shacks for their meals. If the building under construction is large, one labourer is usually fully occupied with keeping all the shacks heated.

Wood stoves are still very commonly used for heating shacks. Not only do these stoves heat the shacks, but they are also used for heating the meals. The design of such a stove is described above. The stoves are heated with waste wood; however, in individual cases oil units are installed.

At present electric heating is being used increasingly for the shacks. The heaters usually have the form of coil radiators or panel radiators (filled with water or steam). Radiators filled with water are safest against fire, but it is clear that from the point of view of economy, this type of radiator cannot be fully utilized. One might even conceive an electric radiator which is not filled with water and which is so designed that the surface temperature cannot exceed say +60°C., thus eliminating the danger of overheating. These electric radiators may be combined with electrically heated compartments for warming the meals and are relatively inexpensive in operation. Furthermore, they scarcely require attendance.

Electric radiators with accumulators are scarcely suitable for heating shacks. They are designed in such a manner that they automatically switch on during off-peak periods when the electricity is cheaper. The heat produced by these radiators is not uniform and is frequently given off at the wrong time.

Oil heaters for heating shacks are also more commonly used today. They require much less attention than wood stoves. The Quakoil is such an oil heater. According to the pamphlet it is completely automatic and, apart from its installation and refilling with oil or gasoline, it requires no attention at all during operation. This heater is connected to a sheet-iron pipe, which carries off the gases. The heater is a hot-air circulator, indicating that the heat is not given off by radiation but that the hot air is circulated. The temperature of the outer jacket is slightly higher than room temperature, except at the upper part where the hot air emerges, and no discomfort is felt near the heater. Lunches may be heated on top of the heater (cf. Fig. 37).

Hot-air heaters are now also being used in shacks. The so-called KV heater is a hot-air heater run by electricity (cf. Fig. 38). The air is drawn into a unit by a fan and heated by six battery cells and is exhausted through air drains provided with valves. The unit is adjusted with a thermostat and the current consumption is relatively low. However, the initial outlay is relatively high but is compensated by low operating costs.

Another hot-air heater is the VT heater, which is provided with an oil-fired unit. This heater seems to be most suitable for large building sites (possibly for several shacks, which may be heated centrally). This heater consists of a double jacket cylinder and the inner jacket is lined with bricks.

The outer jacket is provided with holes for circulating the air. The flue gases are conducted into the open air through special pipes or through the chimney (Fig. 39).

Even central heating from the boiler plant is now used for large building projects. The heat is supplied by the boiler plant of the concreting installation. Hot water for washing may be supplied in the same way. Coil radiators are suitable. For the sake of economy the use of central heating is recommended only for very large building projects. It would be too expensive to lay pipes and carry out the necessary installations for small building projects. Of course, high-pressure plants are essential.

SNOW REMOVAL, ETC.

This is carried out by unskilled workers and includes keeping the building site clear at all times so that the trades people can work without interruption. It means not only removal of snow and ice from the building site but also the steaming of forms, reinforcements, "plums", etc.

The cost of the equipment required for this purpose is relatively low, but the wages are high. However, work stoppage caused by snowfalls may also prove costly. The morning after a heavy snowfall is wasted from the production point of view, and half a day or more may be needed for shovelling snow.

Fresh snow can be removed more easily than packed snow and should also be removed where, by coincidence, no work is done at that particular moment.

Steam is being used increasingly in construction work today. Steam is particularly advantageous in places which are not readily accessible, such as reinforcements and forms for walls. Even the forms for slabs and unprotected material for the concrete, e.g. plums, are hosed with steam in many cases in order to remove the snow.

Obviously steam can never take the place of snow removal which is necessary after each snowfall. The handling of steam requires a certain amount of care in connection with bricklaying, since its moisture is too readily absorbed by brick and light-weight concrete.

TEMPORARY LIGHTING

Darkness is the third factor making winter construction difficult. Of course daylight is utilized as much as possible. Construction work must be carried out in a given order irrespective of the light. After sunrise and before sunset there is frequently adequate daylight at the building site, but at other times artificial light must be resorted to for: (a) overall visibility, (b) outdoor work, and (c) indoor work.

(a) The overall illumination at the building site is needed when material and building machinery, e.g. mortar bed, concrete mixer and hoist, are stored in sheds. Light is also needed outside such sheds. The lighting device is simple and requires comparatively little attention. The number of lights is relatively small.

(b) The following types of outdoor work require lighting: foundation work, concreting and bricklaying. A number of special measures must be taken here and strong lighting units are required for foundation work and concreting. These units must be provided with reflectors and must be placed high enough above the building site to avoid shadows and so as not to hamper movement. For bricklaying additional lights are required on the spot so that the bricklayers can read their levels.

In Denmark tests were made with a "standard installation" for temporary lighting. It is intended for the building of houses having depths up to 12 m., where bricklaying is carried out preferably from scaffolds outside the building. The installation consists of a standard battery which can easily be moved from one building site to another. As can be seen in Fig. 45, lamps are mounted at equal intervals all around the building. The light fixtures are fastened to clamps in order to prevent them from swaying in the wind and to prevent shadows from interfering with the work at the building site. The clamps in turn are mounted on standards, which are raised as the shell is being erected. In Sweden, outside scaffolds are not used for the supporting brickwork. Therefore the "standard installation" in this form is not suitable for Swedish conditions. Of course it is possible that the Danish idea, adapted to Swedish building technique, would provide a quieter and more even lighting for the building site than the strong arc lamps which are most frequently used in construction work in Sweden and which have a tendency to dazzle. Above all, it is most important that shadows do not interfere with the work.

(c) Light for indoor work must be provided by lamps at the spot where work is carried out. This involves more complicated arrangements than outdoor lighting. A crude power line, i.e., a supply line, is joined to the shed housing the electric plant of the building and is led to the different apartments through the telephone input openings, rubbish chute or elevator shaft. On each storey a number of wall outlets are connected to the supply line, from which the required number of inspection lamps are drawn to the different working locations.

The temporary lighting such as it is at many building sites today leaves much to be desired. It affects the pace and quality of the work as well as the welfare and safety of the workmen.

PLANNING OF WINTER CONSTRUCTION

At any time of the year the different tasks at a building site are closely linked with one another. Stoppage for one group of workers immediately sets off a chain reaction in a building under construction. In winter such a stoppage may interrupt the entire working process, because if it comes to the worst the winter weather may cause additional stoppages, which throw the entire planning into confusion.

Planning for winter construction is equivalent to preparation against the winter conditions*. Since the "normal" building time of an apartment house is now generally a year, a certain amount of work must be carried out during the winter, in other words, today most construction work includes winter construction as well. The time at which the building in question is started determines the extent of winter construction, i.e., how much of the different types of construction work is carried out in winter.

Owing to winter weather conditions various types of construction work are subject to varying additional costs. Hence the stage at which a building is at the time when winter delays are expected determines the amount of additional costs and also determines the way in which the planning is carried into effect. If the cold weather starts just when the foundation is about to be poured, the preparations and measures required differ greatly from those after winter has set in when plaster work is about to begin. The time at which the construction gets under way thus is an important factor in the planning and in estimating the additional costs. The earlier the contractor is informed of this date the greater will be his chances of procuring the required machinery and labour in time.

*For the sake of economy a great deal of time and care should be devoted to the details of planning.

The time-table should be worked out at an early date in order to have sufficient time for preparing the different winter measures. Sufficient room must be provided for parking machinery depending on the extent of the construction work in question. The fact that planning means being prepared for winter conditions is equally important. Furthermore, preparations must be thorough and adequate. The extent and type of the entire building district is important in this respect. Construction work can usually be kept going more easily (e.g. by heating) on a small house than on a large one. In a building district where houses are scattered more attention must be paid to the distribution of water and heat than where the houses are close together.

Drawings and specifications must be prepared carefully and studied in detail in order to avoid last-minute changes. Work stoppage owing to changes may be very irksome during the winter. Early preparation of carefully detailed drawings is also important so that the contractor can order the material (e.g. from the lumber yards, etc.) as early as possible.

In calculating the material requirements great importance should be attached to construction work carried out during the winter so that the orders for the delivery of material can be prepared in detail and delays thus be avoided. Materials requiring costly protection should not be stored before winter begins. This method of ensuring delivery of material would be too expensive. It would be more advantageous, if possible, to make arrangements with the suppliers for continuous delivery of small quantities of material to the building site in agreement with the time-table.

Key objects which are essential to the planning of the entire building must be given preference, as, for example, certain types of foundation work. Likewise, the permanent heating plant occupies a key position in the planning. The sooner it starts operating, the more can be saved on other temporary heat sources*.

As soon as the pipes in the basements are laid the basement floor should be finished without delay. Then certain types of outdoor work could be carried out in the basement. The basement floor also provides a more convenient foundation for the ram for settling the forms for basement joists than the rough soil does**. The window frames must be ready to be put in place as soon as the shell of the building is finished. From time to time it may be necessary to make minor changes in the planning of certain tasks in order to keep construction going.

Work reserved for periods of poor weather includes finishing walls, interior plastering, etc. When the winter weather becomes severe only indoor work is carried out and preparations for this must be made in advance.

Work in workshops and plants is not affected by the weather. Therefore, the increase in the manufacture of prefabricated building parts is an important step in the right direction for smooth winter construction. For example, it is easier to install prefabricated stairs than to pour concrete stairs during the winter. Likewise, various fittings, wrought-iron parts, interior woodwork, etc., should be obtained exclusively from the plants. This is being done increasingly today.

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* Putting the permanent heating plant in operation at the earliest possible moment is of prime importance.

**The basement floor must be finished as early as possible. This facilitates carrying out work reserved for unfavourable weather.

For long-range building activity it would be more economical if an attempt were made to reduce the building time and to use more prefabricated building parts. This would be an important factor in the reduction of building costs. It is reasonable to assume that in the future prefabricated parts will come into their own.

In many respects foundation work is one of these key tasks in construction work and should be given preference in the planning. If the fixed time for starting work prevents the laying of the foundation during the warmer part of the year, excavation work should begin before the soil freezes. Therefore, it is expedient to start digging the excavation before building activity comes to a standstill*.

If possible, the water system should be in operation before the frost sets in.

The road approach to the building must always be in perfect shape before the frost sets in.

The permanent system of drains should also be ready as soon as possible so that it is in operation while the building is being erected. A well-drained foundation soil reduces the danger of frost.

Concreting requires the most careful planning for the winter**. The amount of concreting to be done during the winter should be known so that a boiler plant can be installed

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* Foundations should be back filled as soon as possible. The soil for back filling is often left at the building site and is apt to freeze, thus interfering with the progress of the work.

**Concrete work is more sensitive to changes in temperature than other outdoor work.

if necessary. If this is so, it will be necessary to decide between a low-pressure and a high-pressure boiler. The shape of the building is also of some importance. Different measures are sometimes required for a long, low narrow house than for a high compact one.

Heating requirements should be based on the work schedule so that a maximum working rate can be maintained right from early morning. This means that temperature observations must be made and that the weather reports should be studied*.

In poor weather bricklaying must often be reorganized. As a rule it should not be too difficult to keep the bricklayers occupied with some other work. For example, they may be employed with interior plastering in the basement or rooms that have been completed and with finishing walls, etc. Of course, it is most important that any such reorganization does not interfere with other work.

Bricks and light-weight concrete should not be damp on delivery to the building site and must be stored in such a way that they cannot absorb moisture.

The measures required for interior plastering during the winter increase the cost appreciably. Therefore, it is important that interior plastering be planned with the greatest economy possible. This applies particularly to drying devices and covers.

Starting the permanent heating plant as soon as possible has a decisive effect on the results of plastering.

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*Why not have a radio in one of the shacks so that the weather report can always be heard?

If the windows have not been placed, the casings should be constructed in such a way that they can be used from one building to another, e.g. blinds of sacking.

The drying devices should be adequate for all the plaster work involved. Of course the capacities of the individual devices must be known*.

Proper maintenance of the building site during the winter is essential. Therefore, the building must be left in such a state at the end of the day that work can begin the next morning without delays, even if the weather is unfavourable. In covering the building material the danger of snow and night frost should be considered.

The size of the building determines the type of heating device to be used for the shacks. For a large building central heating from a boiler plant would be most economical, but electric heaters or kerosene heaters are often more suitable for small buildings. Automatic heating in one form or another is more economical in the long run than, for example, the conventional stove, despite the higher first cost**.

Thermostatically-controlled heaters should be most economical in operation. They can be set at a certain minimum for the air temperature during the night. Thermostats may be used for both electric heaters and oil heaters. Removal of

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* "Winter for interior plastering" coincides with "winter for concreting". In order to maintain costs for interior plastering during the winter within reasonable limits, good planning and the right kind of drying devices are needed.

**Mechanization pays in the long run as far as heating installations for winter construction are concerned.

snow during the winter often makes it necessary to have a gang of workmen shovelling snow before the regular working hours so that work can begin at 7.00 a.m. Road approaches and supply roads should be shovelled in plenty of time before work begins in the morning*.

In order to be economical, temporary lighting should consist of portable installations which can be moved from one building to another without making too many changes or using too much material. This would considerably reduce the cost of installation.

Financial Preparations

As mentioned in the introduction there has been for some time a trend towards year-round building activity. During the past decade great strides have been made towards achieving this aim by distributing times for starting different types of construction work over the whole year. Thus due attention has been given to this legitimate social aim of providing work for the entire building trade the year round.

However, it is necessary that those who are financially responsible for a building should fully understand what is implied from the economics point of view by starting different types of construction work at different times. It means that the building costs must be checked in detail and systematic accounting must be applied. Only by watching the building costs closely can the economic consequences of winter construction be fully understood. Unforeseen factors, such as changes in the weather conditions, may interfere with the organization and measures taken at the building site; unexpected fluctuations in the price level, etc., affect the estimates, or, at least, complicate them.

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*"Snow is most easily removed if this is done at once" is a Danish slogan. It equally applies to Sweden.

MISCELLANEOUS POINTS

Construction work is carried on the year round in practically all parts of Sweden. In conclusion, therefore, it should perhaps be pointed out that winter construction still involves a number of unsolved problems. Only a few of them, especially those of immediate interest, are mentioned here:

1. To determine from an unbiased comparison of the different types of boiler plants for concreting installations which would best satisfy the need of the building contractor.

2. A high-pressure boiler especially designed for concreting is needed to replace the old tractors, which were originally intended for farming and which are no longer manufactured. Such a boiler should have a water tank of greater capacity in order to reduce the variations in steam-pressure. The boiler would then not be so likely to boil dry. A steam-pressure of 3 to 5 kgm./sq.cm. is fully adequate for building purposes. The tractor's steam pressure of 10 - 12 kgm./sq.cm. cannot be used effectively. In addition to generating steam, the boiler should heat the water directly.

3. Practical experience with present methods of pouring concrete during the winter should be reviewed and at the same time readings of the temperature of the concrete at different external temperatures and the strength during hardness tests at different stages should be recorded. The study and analysis of concrete that did not set would be a good means of finding a better winter concrete than that generally in use today.

4. It is generally thought that the use of coke braziers under concrete slabs promotes the formations of a fatty surface on the concrete, with the result that the ceiling plaster then adheres poorly and possibly falls down. This matter should be investigated in greater detail.

5. The freezing point of mortar can be reduced by chemical addition agents, such as chloride or other metal chlorides, alcohol or a special antifreeze, but at present very little is known about the danger of blooming out. Salts and liquids containing chlorine cannot be used along with iron since they promote rust formation.

These are a few examples of some of the more urgent problems. Possibly there are a number of other interesting problems, which will be given due consideration as the discussion on construction continues.

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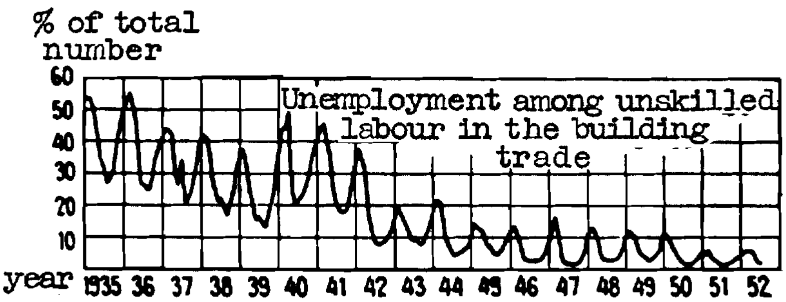

Fig. 1

Seasonal unemployment in the building trade has all but disappeared. Only ten years ago it was considerable and was most marked for unskilled labour. What is left now in midwinter is merely the type of unemployment occurring when workmen change from one building project to another(7).

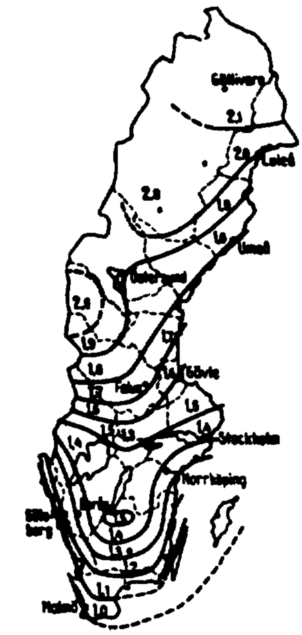

Fig. 2

"Unfrozen ground" in different parts in Sweden. The numbers give the approximate values for the unfrozen ground below the surface, in metres, for the regions marked by solid lines. (According to BABS).

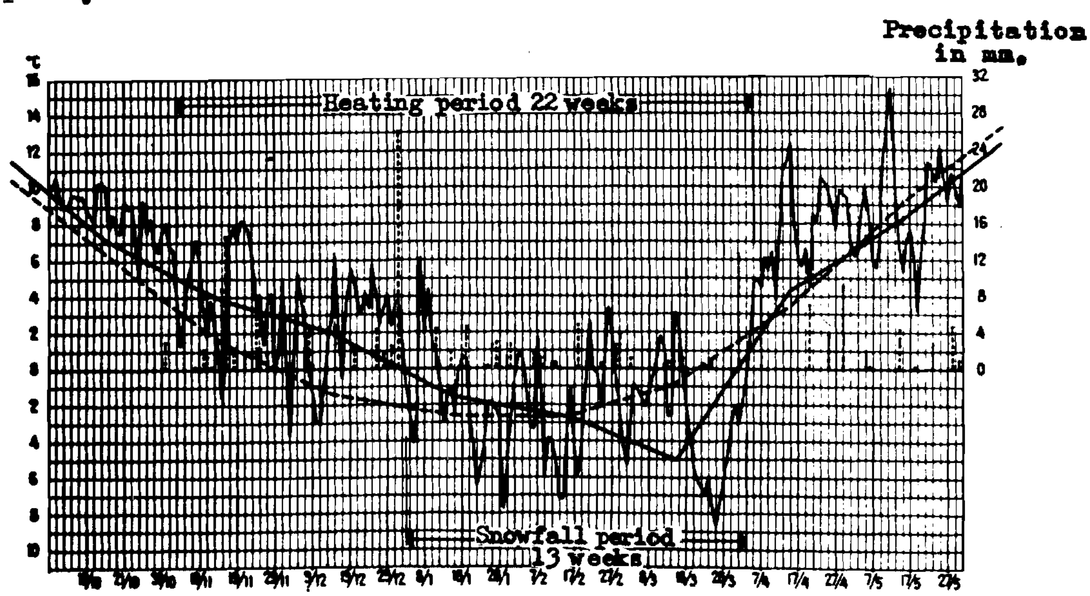

Fig. 3

——————— average monthly values for the heating period calculated from the temperatures at 7.00 a.m.

------------ average monthly values for the years 1901-30.

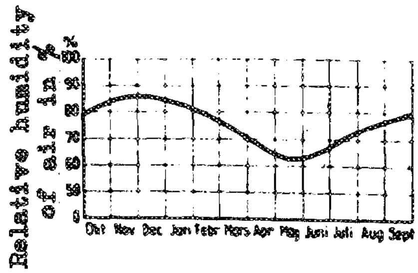

Fig. 4

Although the absolute moisture content of the air is low in winter, its relative humidity is higher than in summer. This means that its moisture-absorbing capacity is lower. The diagram shows the variations of the relative humidity of the air during a year in Stockholm (according to the handbook Bygg).

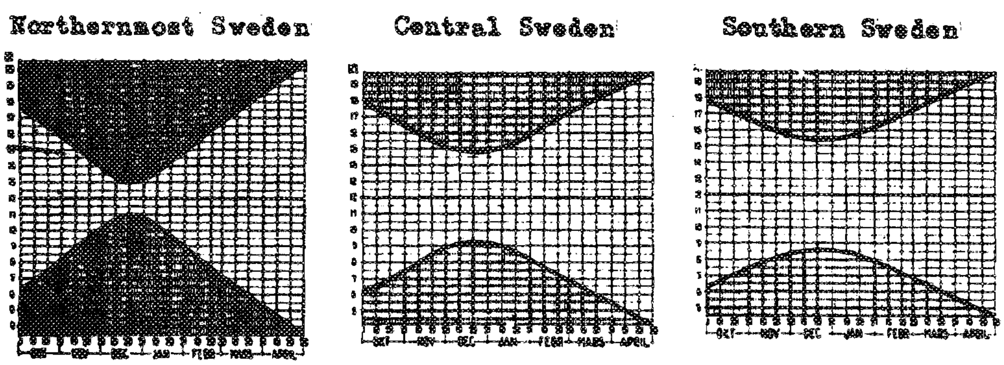

Fig. 5

Hours of daylight (i.e., diffused daylight) in different parts of Sweden. A light intensity of 500 lux is assumed to be the minimum amount of light required for carrying on construction work without artificial light. The diagrams are based on data by G. Pleijel.

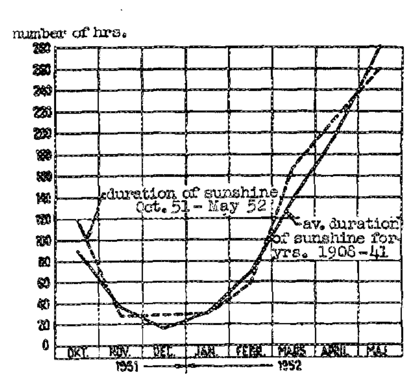

Fig. 6.

Duration of sunshine in hours per month for the time from 1st October, 1951 to 1st June, 1952 (dotted line). Average duration of sunshine calculated for the years 1908-41, (solid line). The diagram refers to Stockholm.

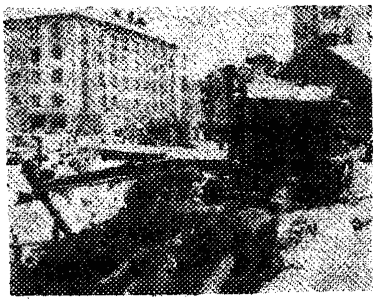

Fig. 7

The excavator works despite the snow. A strong excavator works through an ice crust 25 or 30 cm. thick.

Fig. 8

It is much cheaper to cover the ground with straw than digging the excavation after the ground is frozen(11).

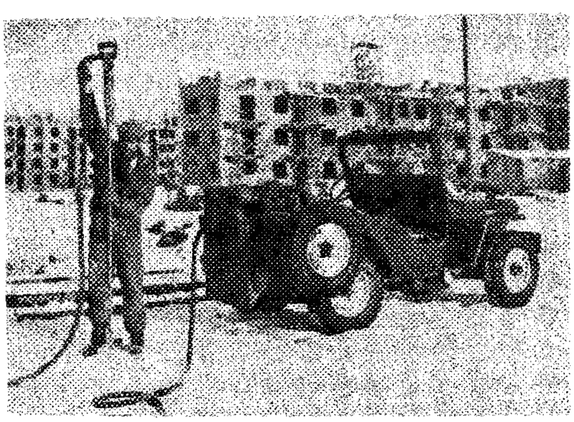

Fig. 9

The jeep with the compressor unit is efficient and versatile. Here a hole is being drilled for blasting the ice.

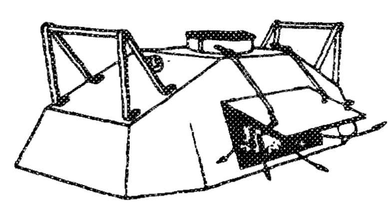

Fig. 10

The drying unit ABIKO was designed for the purpose of thawing frozen soil. The device is heated with charcoal and according to the directions it dries with both hot air and radiant heat. It can even be used for thawing and heating the material making up the concrete as well as for drying purposes.

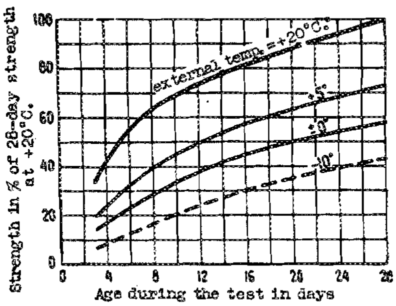

Fig. 11

Increase in the strength of concrete containing standard cement and having the "normal" composition at different temperatures of hardening (i.e., external temperatures).

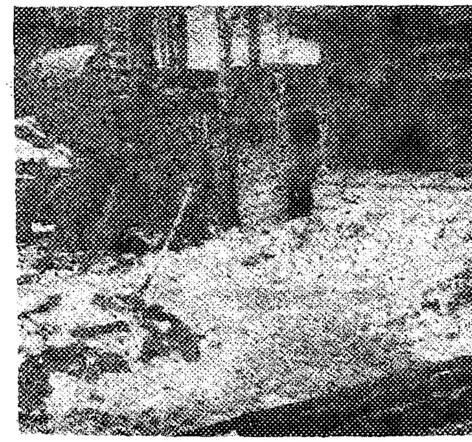

Fig. 12

If sand and gravel are left unprotected, the view presented by the concreting installation here is not exactly inviting.

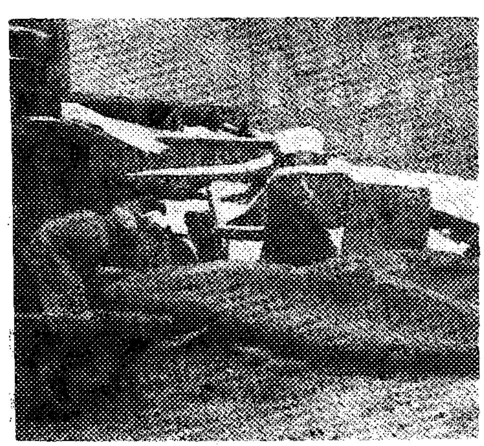

Fig. 13

If the sand is protected by tarpaulins it is much easier to cart. The wheelbarrow shown is of the old type. During the winter the old-time wheelbarrows are frequently preferred to modern carts because sand moistened by steam does not readily freeze to the bottom.

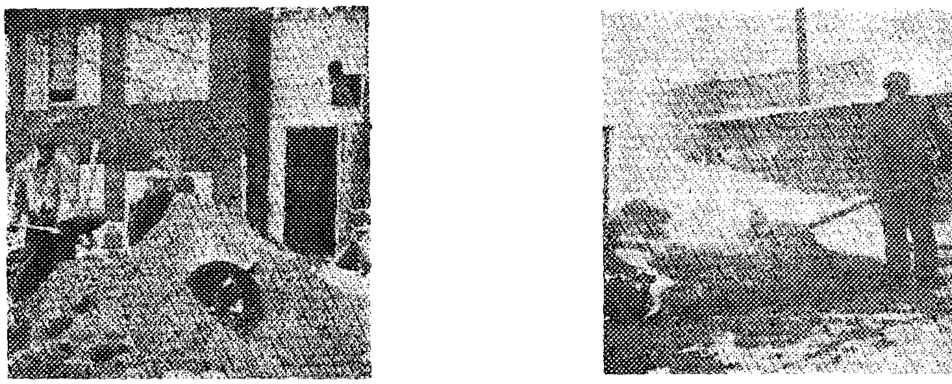

Fig. 14

The sand brazier as a heating device has long been a common sight on constructions. Today in most cases steam jets are used for heating the sand.

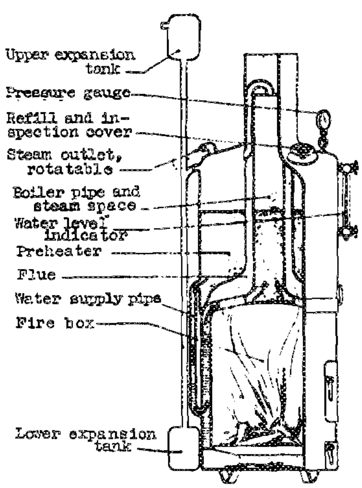

Fig. 15

Sectional drawing of low-pressure boiler (Osby design).

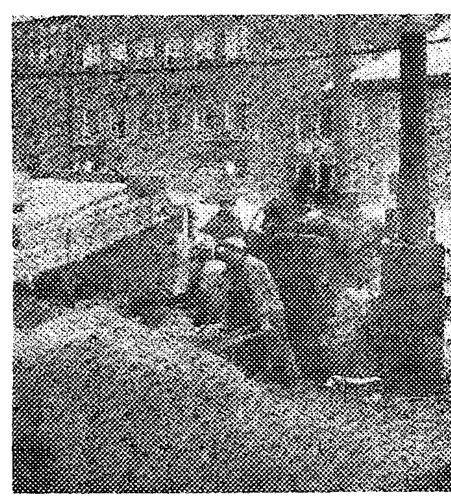

Fig. 16

The low-pressure boiler (Osby design) is a heating device which is easy to operate and is movable. It is suitable for small constructions. As can be seen, it has a separate water heater. It generates between 60 and 170 kgm. of steam per hour, depending on its size. The Osby boiler can be supplied for superheated steam up to +180°C.

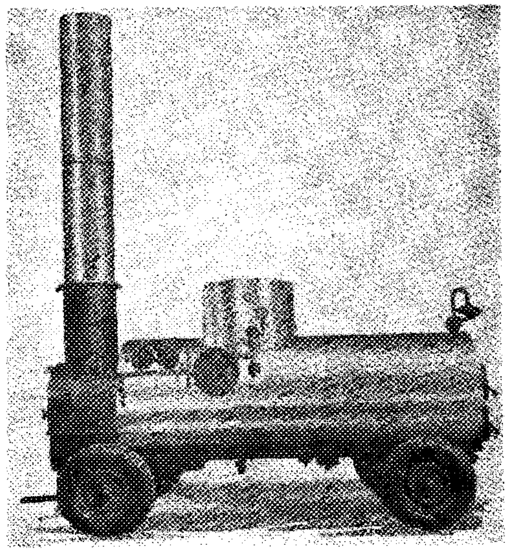

Fig. 17
Low-pressure boiler (VEÅ design) with built-in filament battery for heating the water.

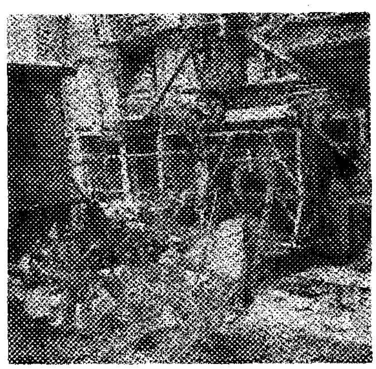

Fig. 18
The water tank above the concrete mixer is provided with a float and operates more or less like an ordinary flush tank, i.e., it fills automatically after supplying the mixer with water. The water is heated with steam from a high-pressure steam generator with nine steam outlets.

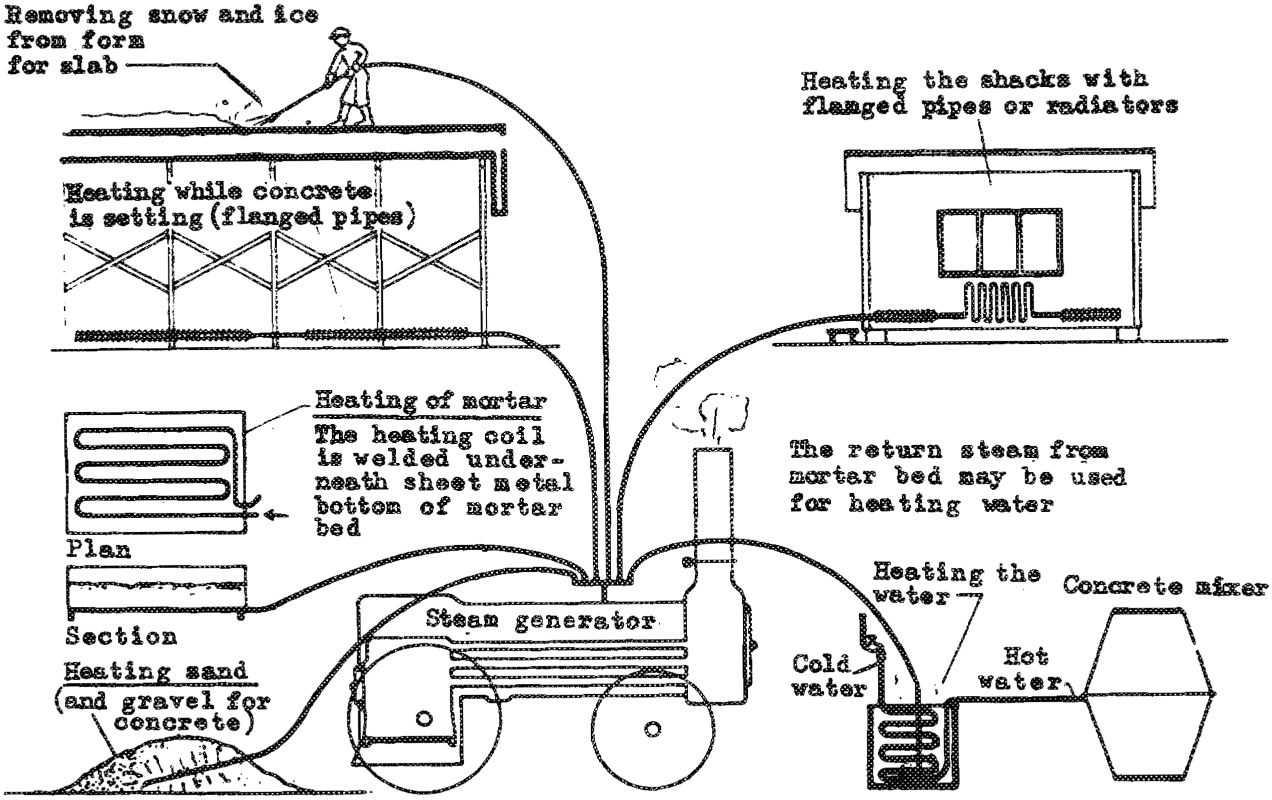

Fig. 19

A large steam generator heats the gravel, keeps the moulds free from snow and ice and heats the water required for pouring and the water for mortar and stuff as well as the water for washing. It supplies central heating and heats the mortar bed.

Fig. 20

The electrically driven cross-cut saw makes it possible to use waste wood from the building operation for firing without high labour cost.

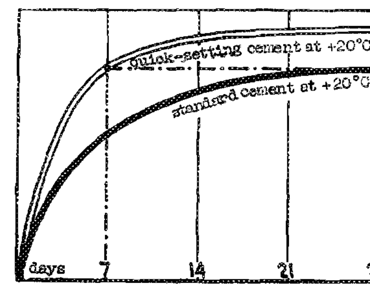

Fig. 21

Quick-setting cement imparts the same strength to the concrete in one week as standard cement does in four weeks(11).

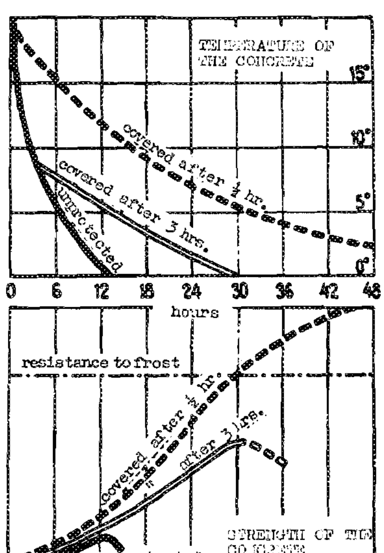

Fig. 22

If the concrete is covered within the first half hour after pouring the concrete becomes frost-resistant more rapidly. After three hours it may be too late. The diagrams are based on data from(11).

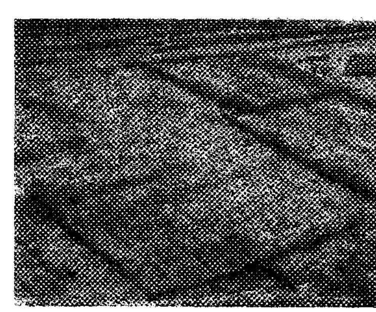

Fig. 23

Straw mats on freshly poured concrete provide effective insulation, although in Sweden they are quite expensive(11).

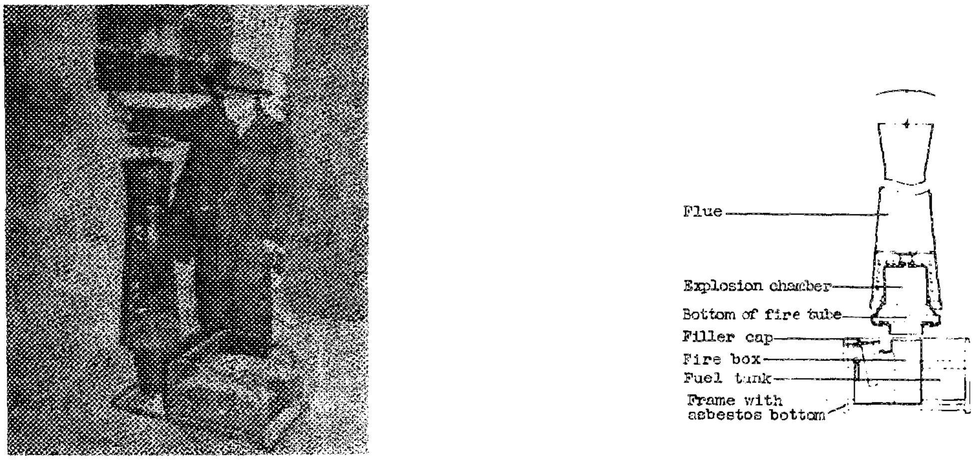

Fig. 24

The kerosene-heated Luntork is used for many purposes in construction. It serves for heating the freshly poured concrete, drying the plaster and providing a pleasant temperature for working. It is well suited for small spaces. The heater can be so adjusted that it supplies between 7,000 and 25,000 kcal. of heat per hour. During 12 hours of operation the effect is gradually reduced from 25,000 kcal./hr. to an average of 17,000 kcal./hr. The average consumption of kerosene is given as 2.2 litres/hr. Beside the photograph the heater is shown in cross-section.

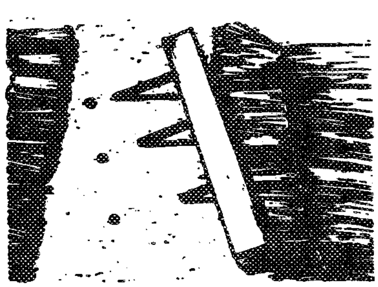

Fig. 25

With a simple device small holes of varying depth can be made to enable the temperatures of the concrete to be checked while it is setting.

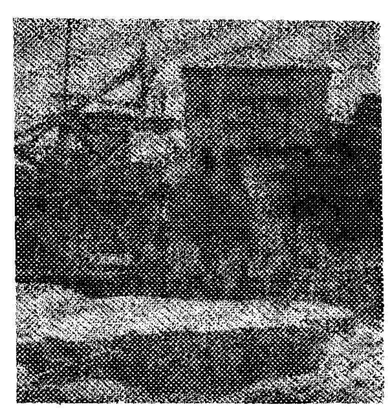

Fig. 26

Bricks and light-weight concrete must be kept dry and well covered. If the bricks are dry they will rapidly absorb the excess water in the mortar, thus reducing the danger that this water might freeze during bricklaying. In stormy weather the tarpaulins may be fastened with clamps instead of being weighted down with bricks.

Fig. 27

In winter it is particularly important to keep the mortar soft. This is facilitated by mechanical stirring. A stirrer (Limak design) is shown in the figure.

Fig. 28

Built-in mortar bed.

Fig. 29

Parallel-block masonry. A special tool distributes the mortar in parallel strings[1].

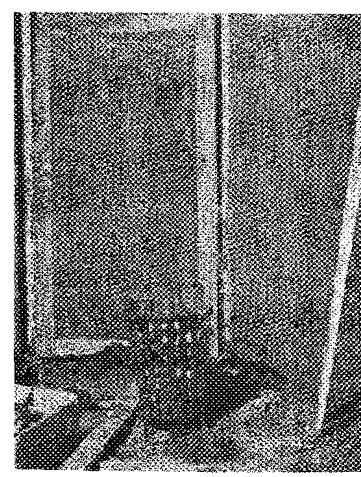

Fig. 30

It is claimed that no device can compete with the coke brazier in efficiency. An argument in its favour is its effect on the carbonization process, whose importance for the drying cannot be exaggerated. Large amounts of heat are needed for drying. It is estimated that coke braziers produce between 7,000 and 15,000 kcal. of heat per hour, depending on their size. Sacking on wooden frames is an ordinary but entirely effective means of covering windows, as shown in the figure.

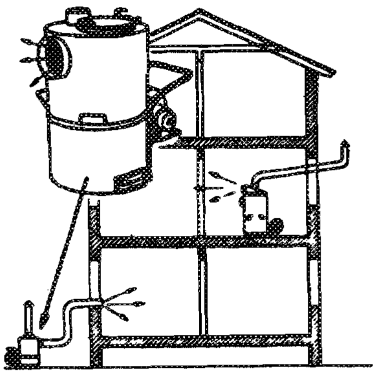

Fig. 31

Example showing how hot-air heaters may be mounted. They circulate the air and thus drive the moisture out of a building.

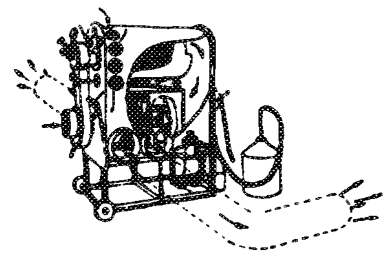

Fig. 32

Oil-fired "Monsun" (Bahco design). This type of hot-air heater is frequently seen on constructions. It produces a mixture of air and gas of approximately 2,200 cu.m./hr. at a temperature of +130 to +190°C. The oil consumption is from 7 to 10 kgm./hr.

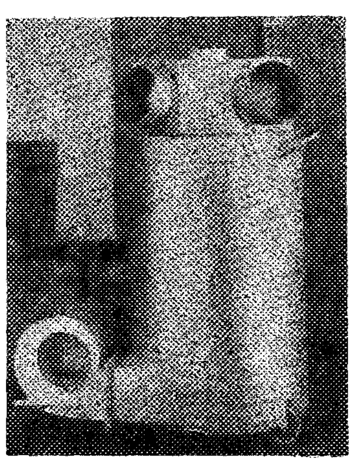

Fig. 33

Building drier (BAB design). The drier is provided with a centrifugal blower and produces a gas-air mixture of 2,500 $m.^3$/hr. The temperature of the exhaust is approximately +100°C. Its capacity is 49,000 kcal./hr. The drier may be fired with boiler wood, waste wood, peat, sweepings, etc. The type shown in the figure is on wheels.

Fig. 34

Uma-torken is a small, readily transportable and quite effective forced hot-air heater. Its capacity is 75,000 to 150,000 kcal./hr. The unit produces a gas-air mixture of 2,000 cu.m. per hour. Its oil consumption is 2 - 10 kgm./hr.

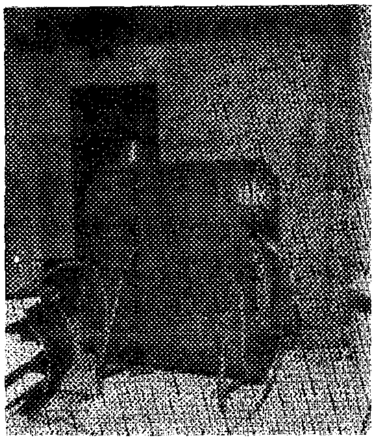

Fig. 35

The OK unit is provided with a high-pressure nozzle and separates the flue gas from the hot air. The unit has a capacity of 2,500 cu.m. and it heats the air to a temperature of 80 - 100°C. The temperature of the outgoing flue gases is 180 - 200°C. In continuous operation the oil consumption is 4 - 8 litres/hr.

Fig. 36

The wood stove still is the heating device most frequently seen in workmen's shacks. Note the arrangement for drying clothes above the stove. Although the interior of the shack looks cheerful nobody could maintain that the old-fashioned wood stove increases the comfort in the shack.

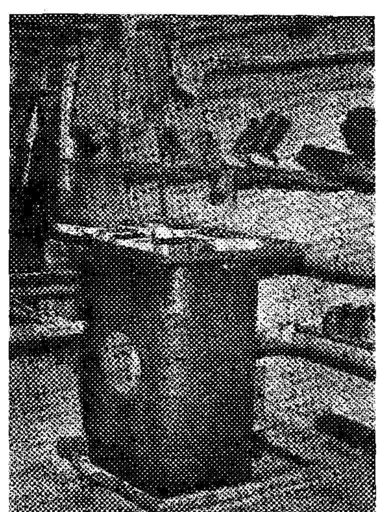

Fig. 37

The Quakoil is a kerosene-fired heater, which requires little attention. Its heat capacity is adjustable between 1,700 and 17,000 kcal./hr. The Quakoil Minor has a maximum heating capacity of 350 cu.m. The fuel consumption is 0.2 - 1.5 litres/hr. Note the lunch boxes on top of the heater.

Fig. 38

The KV heater is heated by battery cells with a total effect of 18 kw. and produces 2,000 cu.m. of hot air per hour (+50°C.) at a temperature of +10°C. of the intake air.

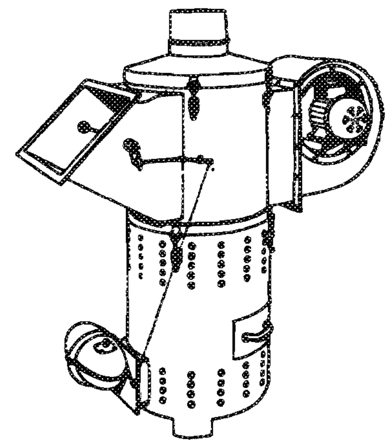

Fig. 39

The VT heater. A centrifugal blower or propeller fan circulates the air. At a flue-gas temperature of +250°C. an air-gas temperature of 100°C. is obtained. The fuel consumption is 2 - 3 litres per hour.

Fig. 40

Steam should be utilized as much as possible, for example, for the forms for walls which are not readily accessible. Steam saves time and labour. However, steam should be used sparingly in the vicinity of masonry. Steam cannot be used either when the snow cover has thickness of more than a few centimetres.

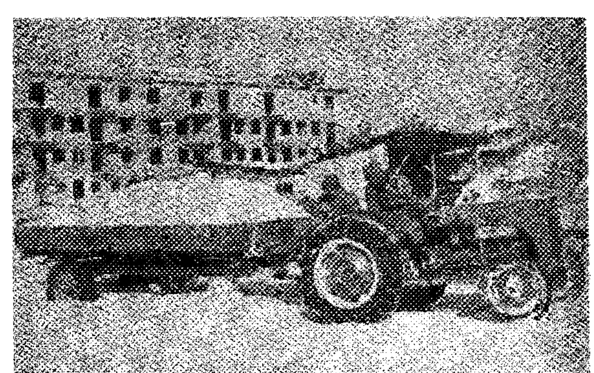

Fig. 41

Tractors are often used today for transporting material from large constructions. In the figure the tractor is struggling with the snow.

Fig. 42

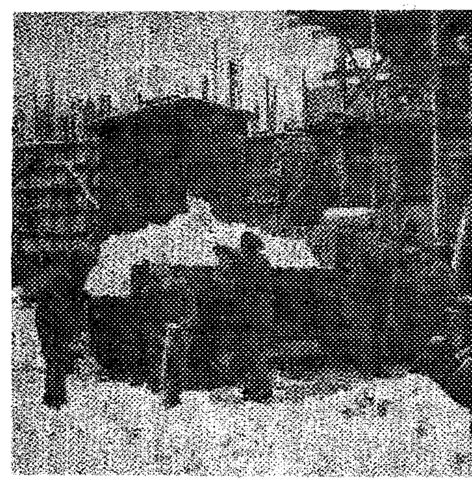

Fig. 43

Shovelling snow is unproductive work, which takes workmen away from more productive construction tasks.

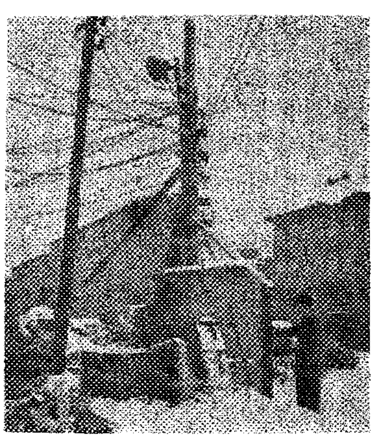

Fig. 44

During the summer the elctric-light installations need not be as complex as that shown here. This installation provides both heat and light. Darkness during the winter makes large arc lamps essential for outdoor work.

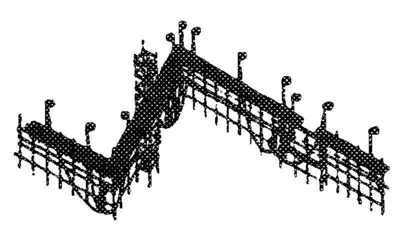

Fig. 45

The "standard installation" is a Danish suggestion for temporary outdoor lighting. Reflective enamel screens, 40 cm. in diameter, are mounted five metres above the work site and turned 45° inwards, thus illuminating the entire building site. The maximum distance between the lamps is six metres(9).

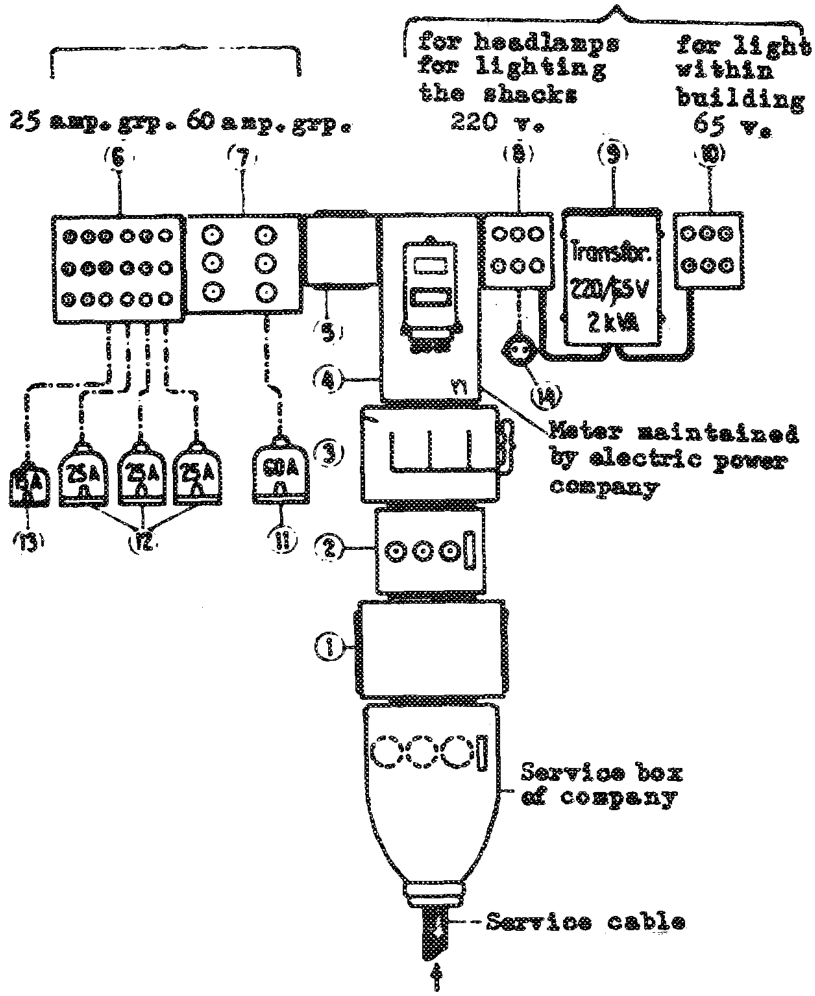

Fig. 46

Equipment of the shed housing the electric plants. (The lighting within the shed is not included). It pays to arrange for adequate light for indoor work. The fact that construction is not stationary is no reason for trying to economize on light. Lighting constitutes only a negligible amount of the additional costs for winter measures.

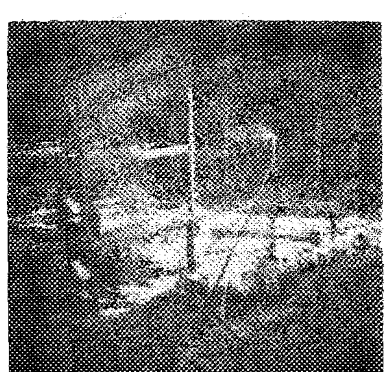

Fig. 47

Example of poor lighting with shadow effects.