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DESIGN AND CONSTRUCTION OF PHYTOTRON-GREENHOUSE COMPLEXES

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Abstract. *A brief historical analysis of the experience of development of structures and equipment for the study of plants in artificial conditions is given. The analysis of constructions and parameters of modern phytotrons and greenhouses for carrying out scientific researches in agrarian institute establishments is executed. The technological structure of phytotron greenhouses is considered on the example of the scientific center of grain research. Spatial planning solutions of the first floor of the laboratory complex and the block of greenhouses-phytotrons for search works are developed. It is noted that the uniqueness of equipment and engineering systems require appropriate organizational and technological justifications for construction and installation work.*

Keywords: *phytotron; greenhouses; spatial planning decisions; research technology; technology and organization of construction.*

Introduction

Modern research centers for the development of selection and genetics of the grain group of agro-industrial products are designed to provide engineering and technological capabilities for research, to expand the number of crop rotations several times, to model different operating conditions.

Main text

Such centers include direct laboratory research centers with traditional laboratories, equipped with different types of equipment for their purpose, technological capabilities, weight, size, as well as greenhouses - mini-boxes with modeling and providing the necessary individual temperature and humidity, etc. Outdoor areas with heated soil in the winter-spring period allow the adaptation of plant products.

Ancillary services include preparation of containers with substrate and soil and planting of seeds, sanitary pass, elevators, as well as life providing systems and structures of the complex with energy and technological needs.

The design of such centers requires a detailed analysis and development of the production technological part of the object, substantiation of the requirements of spatial planning decisions, development of engineering and technological systems. The area of greenhouse mini-boxes is 50-100 sq m and provides for the use of the necessary engineering and technological equipment.

The originality of the considered tasks requires detailed elaboration of issues of technology and organization of construction. First of all, for installation of large-sized elements of the equipment, a combination of these processes with technology of construction of a construction.

The development of the agro-industrial complex depends on a stable supply to the market of quality seed products that meet the requirements of today. Modern research centers created on the basis of phytotron-greenhouse complexes are called to receive such products. The latter include specialized laboratories with original equipment.

A method of designing modern phytotron-greenhouse complexes has been developed, which requires at the first stage a detailed analysis of research elements in a specific field of knowledge of agro-industrial production. This allows you to create requirements for the design and parameters of phytotrons and transparent greenhouse units, to develop spatial planning and design solutions, engineering and technological systems and equipment.

The uniqueness of phytotron equipment, its significant parameters in terms of mass and geometric dimensions require special solutions for technology and construction organization, in particular, a combination of installation processes, automatic control of work processes and subsequent operation.

Results

Scientific and technical support ensures the efficiency of many types of production activities. In the agricultural sector, the creation of promising varieties of different crops is based on the use of artificial climate laboratories – special phytotrons and original mini-blocks of greenhouses.

As early as the nineteenth century, agricultural scientists became interested in the issues of artificial plant development. Professor A S Famintsin studied the effects of light on various crops, including algae. He proved for the first time that the process of CO_2 assimilation and starch formation in plant cells is more active under artificial lighting [1]. In the works of Academician K A Timiryazev, in those days it was confirmed that there is no big difference in the effect on the development of sunlight and irradiation from lamps. A method of taking into account the photosynthesis of CO_2 absorbed by the plant, determining the spectrum of chlorophyll use and light assimilation has been developed, and for the first time a substitute for soils, a made substrate, has been used. Almost simultaneously with specialists from Germany, the first vegetation houses (greenhouses) were created at the Petrovsky Academy, including for research. It is shown that such structures, especially with plant lighting systems, allow to accelerate selection processes. The main results of research by Academician K A Timiryazev set out in his doctoral dissertation "On the assimilation of light by plants" (1875) and scientific work "Sun, life and chlorophyll" (1903), which became the theoretical basis for the subsequent creation of modern phytotron-greenhouse complexes.

The active development of this area of research was carried out in the second half of the last century. In the city of Pasadena (USA), on the initiative and under the leadership of F Vent, a climatic complex for the study of plants was created [2], which was named phytotron.

In general, there is no single classification of structures in the world that have the conditions for fully functional regulation of the microclimate. A number of authors have made attempts to do this. Such work is being carried out at the present time [3].

In the Netherlands there are several dozen phytotron-greenhouse complexes (PhGC) in various fields of agricultural science. In the Institute of Selection of Fruit Crops in six greenhouses with an area of 60-70 sq m in winter and summer regulate different temperatures and other differences.

The PhGC At the Institute of Biological and Chemical Research of Field Crops and Grasslands and Pastures, operates with three greenhouses and eight chambers. The most important research is conducted at the PhGC, which operates on the basis of the main research center – Wageningen University & Research (wur.nl). The plant breeding study analyzes, develops, maintains and uses genetic material.

Tools for effective plant breeding are being developed, in particular molecular markers of traits (genes, libraries, maps, etc.) with subsequent storage in the database of phenotypes and their characteristics. Similar areas also work in agricultural institutes and centers of this country.

In Canada, the Agricultural Experimental Station (Lethbridge, Alberta) has one of the most modern PhGCs, comprising eleven greenhouses and about one hundred vegetation chambers. In other cities in Canada (Guelph, Ottawa), as well as in all research departments of agricultural universities and agricultural stations, there are PhGC of various types and kinds.

Currently, most US universities have appropriate facilities and installations of artificial climate. In particular, the PhGC at Duke University (Durham, North Carolina) includes six greenhouses and 47 climate chambers and cabinets, and the University of North Carolina (Rally, North Carolina) has three greenhouses and 58 chambers, respectively, and cabinets.

The Australian National PhGC at the University of Canberra has been operating since 1952. It consists of 15 greenhouse units and more than 50 small and large chambers and cabinets.

In France, the PhGC Research Center in Gif-sur-Yvette is one of the most powerful in the world and multifunctional. Less powerful complexes are also in the cities of Dijon, Montfavet, Luciana and others.

German agar research centers are located in the cities of Leverkusen, Hannover, Kirchen-Hausen, Hessen, etc.

In Japan, PhGC has also been used in agriculture to solve theoretical and practical problems since the early 1950s. In particular, such facilities have been operating since 1954 at Kyoto University of Technology, since 1958 at Tokyo Agricultural University, since 1959 at the National Institute of Genetics in Mishima, and in 1963 at the Hiratsuka Agricultural Research Station and in 1966 near Sapporo.

Modern PhGC have a strong experimental base. The peculiarities of the interaction of proteins with phytotron receptors [4], the joint effect of ozone and drought conditions on the formation of biological volatile organic compounds [5] are studied, and also the peculiarities of growing new substances and materials for the PhGC, in particular champignons, are being studied [6].

In Ukraine, one of the world's most powerful PhGC was created on the basis of the Myronivka Wheat Institute. The total usable area of greenhouses for research is more than 5500 sq m, and three selection greenhouses – 4200 sq m.

Phytotron equipment includes chambers for research at plus and minus temperatures, different levels of illumination of plants, humidity, etc.

Extensive research has been conducted on the basis of PhGC in Myronivka [7], methodological bases of energy-saving technology of growing grain crops in artificial climate and in the field have been developed. Ways of development of adaptive plant growing of artificial climate in interrelation with tasks of selection and seed production of traditional grain and vegetable cultures, and also siderates, medicinal, tropical, stevia, aloe, etc. are shown.

In the Ukrainian Breeding and Genetics Institute - National Center for Seeds and Variety Studies (Odessa) created PhGC consisting of eight greenhouses and more than forty autonomous climate chambers. Fundamental and applied problems of genetics and selection are solved with the further development of research in physiology, biochemistry, immunology and other sciences [8]

Currently in Ukraine, several private agricultural firms and organizations-grain producers are considering the creation of their own PhGC to obtain quality seed material.

Research greenhouses in the cities of Zhodino (Agriculture Center), Nesvizh (Sugar Beet Center) and the village of Samokhvalovichi (Institute of Vegetable Growing) of Minsk region were created for agricultural research institutes and centers of Belarus with the participation of the authors [9].

In Russia, special attention is paid in the PhGC to the study of plant behavior under negative temperature and other adverse climatic influences.

The main research in the PhGC in the Kuban is conducted on sunflower [10], cereals and oilseeds, castor oil [11].

The main principle of such systems is the study of one specific indicator of experimental plant physiology with fixed stable and constant values of other parameters.

Conceptually, the PhGC consists of several technological links combined with the final program of action and should reproduce the given parameters of environmental conditions, as well as be able to provide their variable values within the framework of various methods and experiments.

During the design and construction of modern PhGC consider and solve a number of complex technological and engineering problems (Figure 1).

Engineering and geological conditions of the site affect the choice of structural solution of the structure, capabilities and method of installation of recessed elements. Indicators of average daily and monthly temperatures determine the type of fenced structures, the depth of laying the foundations, the method of providing the estimated design values, etc.

Crucial is the need to create comfortable conditions for research. Technological, production structure of research is determined by the peculiarities of the direction of the institution and crops (cereals, vegetables, potatoes, etc.) for the equipment of phytotrons and greenhouse units.

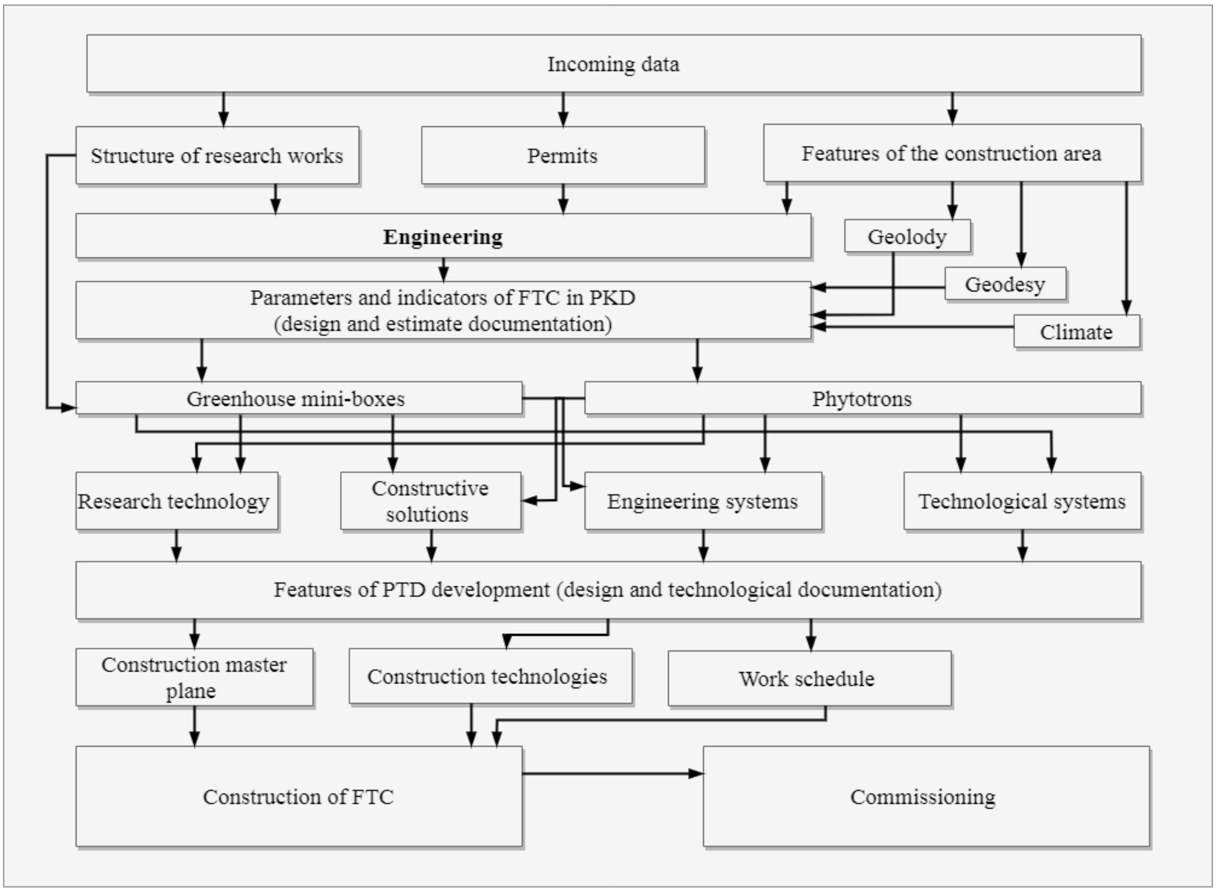

Figure. 1. Scheme of design and construction of PhGC.
Author's development

When forming greenhouse blocks, they focus on typical solutions for span width (6.4; 8.0 and 9.6 m), column pitch (4.0; 4.5; 5.0 m) and height – about 5.0 m. Partitions between blocks are transparent with glass or polycarbonate filling. It is mandatory to install a transformed vertical curtain system to save energy on the outer walls and prevent the negative impact of lighting from adjacent blocks-compartments. Horizontal curtain system is made of two independent elements, at different levels and with different functions: shading (30-40%) energy saving (about 50%) [12,13].

The set temperature parameters are provided, first of all, by a pipe heating system with 4-5 independent circuits and use, if necessary, of additional air heating.

The use of irrigation or fertigation systems is based on soluble units of design capacity with the supply of nutrient solutions on a dropper with a capacity of 1.0-2.0 liters per day.

Direct phytotrons are characterized by size (volume), functionality, energy performance.

Phytotrons, or plants for plant growth, are used in the following two types [14].

1. Block-modular installations of full factory readiness with climatic chambers for plants, crops on the basis of fabrics, and also seeds and insects for the decision of various biological problems. They have the most widespread size 1400 (height) × 800 (depth) × 1980 (height) mm. The set parameters for temperature (-2.0ºC … + 40ºC), relative humidity (from 35% to 80%) with different types of illumination (fluorescent and sodium lamps, LED-light, etc.) are provided. Such solutions are more favorable

for long-term storage, incubation and conditioning of seeds and other biological materials (Figure 2).

a) b)

Figure 2. General view of the phytotron (a) and the equipment hall of the phytotron group (b).

Growth climatic rooms with a cultivation area of 1 to 25 sq m are equipped with shelves with lighting and have a large climatic range with adjustable supply of conditioned fresh air. Sterile humidity is provided by a special steam humidifier.

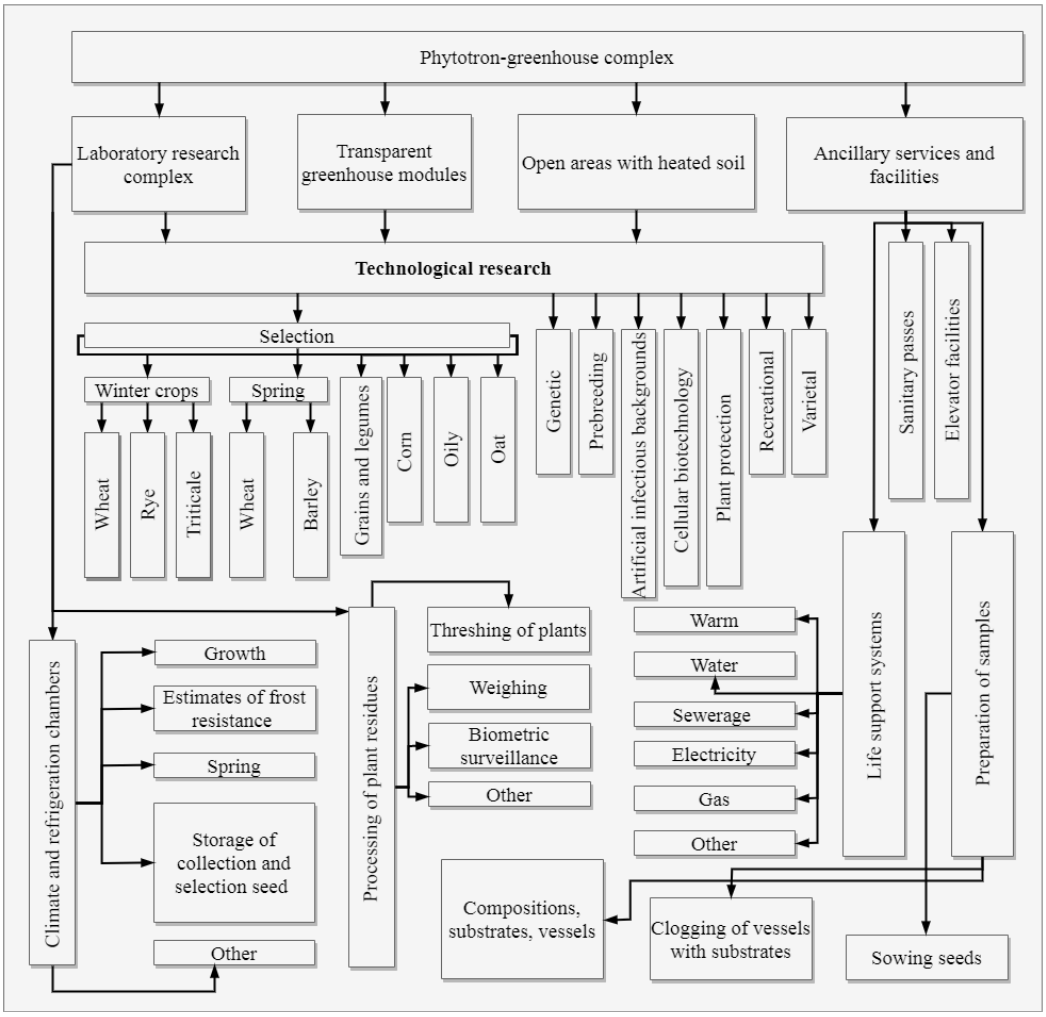

Figure 3. Technological (production) structure of PhGC.

Author's development

Phytotron-greenhouse complex includes the following main elements (Figure 3): laboratory and research building (capital building); transparent blocks in hothouse designs; open areas with soil heating; auxiliary services, facilities and life support systems of the complex.

Technological (production) activities in research institutions for the study of grain crops consist, first of all, in carrying out work with the selection of plants: winter (wheat, rye, triticale) and spring (wheat, barley), as well as with oats, corn, grain-legumes and oilseeds.

In parallel, genetic registration, analytical, varietal, prebreeding, cell technology and plant protection studies are conducted.

These studies are carried out directly in the laboratory building (Figure 4, room 5) and in greenhouse boxes (Figure 4, boxes 10-11). Phytotrons or growth chambers of complete delivery (in particular, room 53 on the first floor) are located on the floors separately in the laboratory building.

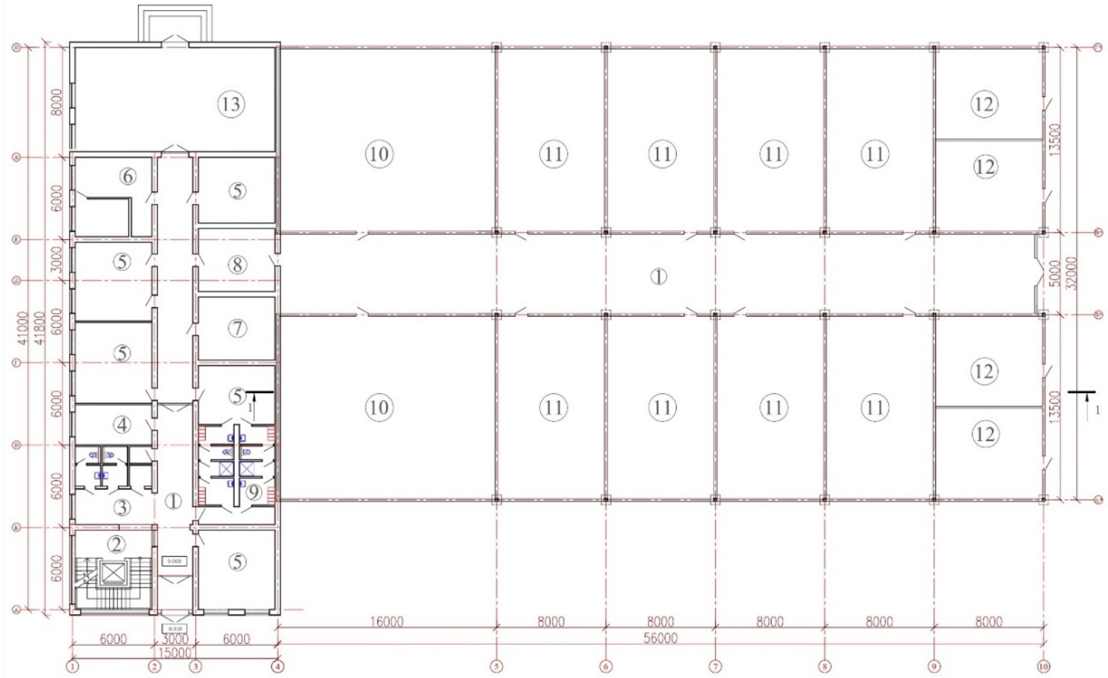

Figure 4. Plan of the first floor of the phytotron-greenhouse complex:
1 *- corridor;* ***2*** *- staircase with a freight elevator;* ***3*** *- bathroom;* ***4*** *- operator;* ***5*** *- research laboratories;* ***6*** *- life support unit;* ***7*** *- service unit;* ***8*** *- vestibule corridor;* ***9*** *- sanitary pass;* ***10-11*** *- mini-greenhouses - boxes of the selection department, respectively: winter wheat, rye and triticale; spring wheat and barley; oats; grain and legumes; genetics and prebreeding, cell biotechnology;* ***12*** *- department of creation of infectious backgrounds;* ***13*** *- hall of growth chambers.*
Author's development

The other area of the basement is allocated for special refrigeration equipment: frost resistance assessments; vernalization; storage of collection and selection seed material.

In laboratories, research is performed using special equipment for threshing plants with stationary and spike threshers, weighing, biometric monitoring, counting seeds with bags, etc.

High requirements are given to the device of special hothouse boxes for storage of artificial infectious backgrounds (Figure 4, boxes 12). These are the requirements for the density of structural elements, the need for separate isolated (Figure 5) inputs and outputs, and so on.

Separately from the building there is an open area for hardening of plants and year-round research with an area of up to 1000 sq m. To provide shading arrange a galvanized metal frame with a movable screen-curtain. Underfloor electric heating systems allow you to plant plants in February-March.

Auxiliary facilities solve the traditional issues of life support of the complex through the networks of electricity, heat, water supply and preparation of raw materials and samples with sowing seeds in separate vessels with substrate or soil. According to separate requirements, a sanitary pass and an elevator are arranged.

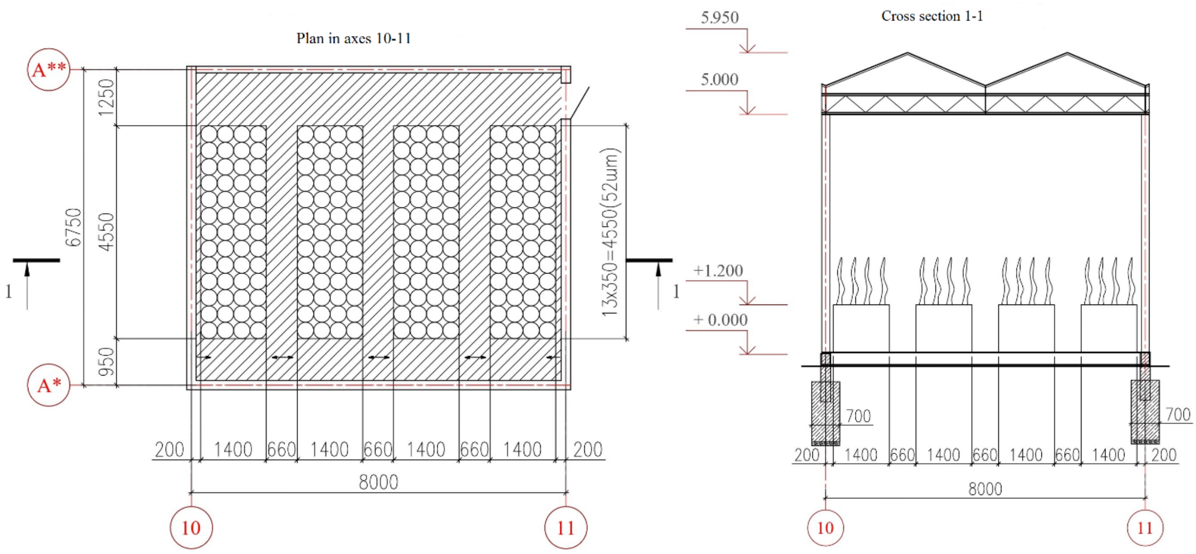

Figure 5. Technological features of plant placement in the plan (a) section (b) of the mini-box of the greenhouse of the department of creating infectious backgrounds.

Author's development

The above, as well as other conditions and features are the basis of design and estimate documentation (Figure 1, block 2). The combination of the requirements of basic scientific research, the features of specific materials and samples in providing comfortable space-planning solutions, temperature and humidity characteristics and other factors determines the importance and responsibility of creating a project.

An important stage of project activity is the creation of design and technological documentation for the direct construction and installation work. Particular attention is paid to the following: dimensions and installation of technological equipment of phytotrons and refrigerating chambers; saturation of greenhouse mini-boxes with engineering and technological systems and equipment; high level of automation of research processes and provision of temperature and humidity regimes.

The result of research**.** The method of designing spatial planning solutions, engineering and technological systems of phytotron-hothouse sets is created.

The three-story research and laboratory building with outbuildings and transparent mini-blocks in greenhouse structures was developed on the basis of research centers for the study of grain crop selection.

Summary and conclusions

In the nineteenth century in the works of Professor A S Fomintsev and Academician K A Timiryazev proved the possibility and necessity of the development of genetic studies of plants in artificial conditions. The creation of the first experimental plants of phytotrons, the widespread development of equipment for such research occurred in the second half of the twentieth century. All developed industrial countries are actively developing this area.

Modern phytotron-greenhouse complexes are high-tech samples of equipment and systems and require the provision of these areas of research and high-quality life support systems.

The design and construction of such complexes involves the use of knowledge systems for research methods of technological features of different crops, the need to ensure appropriate parameters and indicators.

At the same time, high-quality design of construction technology and organization of works is also important.

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