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STRENGTHENING THE TECHNOLOGICAL BASE OF MPR STATE COMMITTEE FOR SCIENCE AND TECHNOLOGY FOR DESIGNING PRODUCTION AND TESTING OF PROTOTYPES BASED ON SCIENTIFIC RESEARCH

ST/MON/82/001

MONGOLIA

Technical report: Alternative energy resources

Prepared for the Government of the Mongolian People's Republic
by the United Nations Industrial Development Organization
acting as executing agency for the United Nations Development Programme

Based on the work of N. N. Koshcheev

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Vienna

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Explanatory notes

In addition to the common abbreviations, symbols and terms, the following have been used in this report:

CSTI	Centre of Scientific and Technological Information
IPT	Institute of Physics and Technology
MAE	Ministry of Agricultural Economy
MFEI	Ministry of Fuel and Electric Industry
MPR	Mongolian People's Republic (abbreviation used only where it appears in project document title)
MWE	Ministry of Water Economy
SCST	State Committee for Science and Technology

CONTENTS

Page

Figures

RECOMMENDATIONS

1. To finalize the technical documentation for the prototypes tested, including the technical solutions derived from the tests and instructions for installing and putting into operation the wind-driven water pumps (TWN-CYO-0.5+2.0 and JSA-0.5); wind-energy aggregate (XYY-1); solar devices for heating water and dwellings; solar elements and solar batteries (Naran-1, Naran-2, Naran-3).

2. To present the final technical documentation in terms consistent with those of existing standards for pilot prototypes. (The most acceptable standard for Mongolian conditions is the United System of Constructor Documentation published by the State Committee for Standards of the Union of Soviet Socialist Republics).

3. To continue research aimed at solving the problem of winter use of wind-driven water pumps and to carry out additional tests on such pumps in accordance with the proposal of the Research Institute of the Ministry of Water Economy (MWE) of the Mongolian People's Republic, elaborated in co-operation with the Soviet research institutes.

4. To finalize the establishment of prototypes of solar houses of 50 m^2 in area and to test solar collectors for air and water heating, accumulator subsystems and dubbing systems as well as solar elements and batteries for supporting adequate living conditions in solar houses during winter.

5. To start local trial production of 150 JSA-0.5 pumps, using equipment presently available in the workshop of the Livestock Research Institute.

6.- To start local trial production of 20 TWN-CYO-0.5+2.0 pumps, using equipment presently available in the MWE workshop.

7. To support the activities of the Laboratory of Solids at the Institute of Physics and Technology (IPT) aimed at improving the technology of manufacturing solar elements by:

(a) Accelerating the supply of equipment, including:

(i) Item 19, laminar flow benches and modules for clean environment handling of semiconductors (producer: Termco Product Corp.);

(ii) Item 20, nitrogen and oxygen gas purifiers (produced in the Netherlands);

(iii) Item 21, capacitance conductance (General Radio, United States of America);

(b) Implementing the project entitled "Development of photovoltaic technology on the base of research at the IPT" as the second phase of project DP/MON/75/006, "Demonstration of new sources of energy in rural development".

8. To prepare a final project document for the establishment of a workshop for manufacturing solar batteries based on technology adopted from IPT and the results of testing Mongolian-made prototypes of solar batteries Naran-1, Naran-2, Naran-3.

9. To implement the Mongolian-Finnish programme for the industrial production of JSA-0.5 pumps, upon supply of machines, tools and other necessary equipment from the USSR.

10. To finalize the technical documentation base of the State Committee for Science and Technology (SCST). The documentation is being prepared based on the feasibility study and preliminary technical assistance carried out by the Novosibirsk division of the All-Union State Design and Scientific Research Institute of the Scientific Academy of the USSR.

11. To elaborate a programme for local industrial production of TWN-CYO-0.5+2.0 pumps and technical documentation for the manufacturing plant.

12. To extend activities aimed at improving helio-technology in the IPT and to implement the project entitled "Strengthening the Heat Physics Laboratory of the IPT of the Scientific Academy to develop helio-energy technology in Mongolia" (dependant on receiving additional assistance from the second phase of the United Nations regional project DP/RAS/84/001/C/01/53, "Regional energy development programme").

13. To implement a project elaborated at the request of the SCST entitled "Strengthening of the national system of scientific, technical, patent and bibliographical information at the CSTI" aimed at introducing modern computer technology and a remote data-processing system in the presentation of information necessary to the establishment of pilot prototypes and the upgrading of economic efficiency.

14. To accelerate the training of the following Mongolian specialists abroad:

Chief, Heat Physics Laboratory of the IPT;
Scientific staff, SCST;
Senior Engineer, Hydrometeorological Institute;
Chief, Repair workshop, MWE;
Chief, Workshop at the Livestock Institute;
Scientific staff, IPT;
Chief, Laboratory of Solid Physics, IPT.

15. To strengthen national capabilities in modern design and technical analysis by:

(a) Establishing an Experimental Design Office (Special Construction Bureau), utilizing the experience of various groups currently working on projects in research institutes and workshops;

(b) Organizing a unit for installing, testing and providing training on pilot prototypes;

(c) Establishing units for the local production of tested prototypes.

16. To commence, without undue delay, the second phase of the project (requiring an additional input of $US 800,000).

I. ENERGY RESOURCES

A. Wind resources

Annual average wind speeds in Mongolia range from 3.5 to 5.9 m/sec for 60 per cent of the territory (table 1). Potential wind-energy resources are thus 836.8 million kW for the territory. Wind energy is available from 4,500 to 5,000 hours per year.

B. Solar resources

The following factors show that effective use could be made of solar-energy devices in agriculture:

(a) Mongolia enjoys 2,600-3,300 hours of sun annually (see table 2), which is significantly more than France (1,750 hours), a leading country in the use of solar equipment and located approximately at the same latitude. The distribution of sunny days is even during the year (data on cloudy days are shown in table 3);

(b) Cloudiness is negligible (figure I) because Mongolia is remote from seas and oceans; thus, the solar radiation is stable;

(c) The dry continental climate (relative humidity about 30 per cent) promotes the power of solar elements by 4-10 per cent and increases their lifetime by 50 per cent in comparison with tropical countries;

(d) In rural areas low population density, a nomadic way of life, and sharp drops in temperature restrict the use of traditional, portable, diesel or electrically powered devices requiring periodic deliveries of fuel.

Thus, an important way of improving agricultural mechanization in widely scattered communities is to provide energy from renewable sources. During the project "Demonstration of new sources of energy in rural development" (MON/73/006) carried out in 1980-1982, various small-scale wind and solar energy devices (e.g. wind-driven generators and water pumps, solar photovoltaic generators and thermal water heaters) were contributed by Finland, France, the United Kingdom and the USSR. They were demonstrated by consultants who elaborated on possibilities for expanding the use of these and similar systems.

In the course of these demonstrations, it became clear that renewable-energy activities should be concentrated on a small number of possibilities lending themselves to adaptation to Mongolian geographical and climatic conditions: wind-driven water-pump aggregates such as "Acrobat" from Finland and "Chaika" from the USSR; and solar units. Accordingly, it was suggested that new, appropriate pilot prototypes be elaborated within the framework of the project.

Table 1. Data on average wind velocities by month, season and year for suitable areas of Mongolia for application to wind-driven water pump and wind energy aggregates

Meteorological station	Average wind velocities (by month)								Month m/s				Average seasonal wind velocity (m/s)				Average annual wind velocity (m/s)
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XII-II	III-V	VI-VIII	IX-XI	
1. Altai	2.7	3.2	3.4	4.6	4.5	3.9	3.3	2.9	3.1	3.5	3.2	3.0	2.9	4.2	3.4	3.3	3.4
2. Arvaikher	2.9	2.9	3.4	4.4	4.4	3.6	3.0	2.7	3.2	3.2	3.1	2.7	2.7	4.1	3.1	3.2	3.3
3. Dalamzagdad	3.4	3.8	4.7	6.1	5.9	4.3	4.3	3.9	4.0	3.8	4.1	3.4	3.5	5.6	4.2	3.9	4.4
4. Saikhan	7.3	5.8	5.6	6.2	5.9	4.7	3.9	4.1	4.2	5.1	8.4	8.6	7.2	5.9	4.2	5.9	6.0
5. Bayankhongor	2.8	2.8	3.0	3.8	3.9	3.1	2.8	2.7	3.0	3.0	3.2	3.1	2.9	3.6	2.8	3.1	3.1
6. Mandalgov	4.5	4.3	4.5	5.6	5.8	4.9	4.2	3.8	4.1	3.8	4.3	4.1	4.3	5.3	4.3	4.1	4.5
7. Sainshand	4.2	4.2	5.0	5.9	6.0	5.2	4.6	4.0	4.4	4.1	4.2	4.1	4.2	5.6	4.6	4.2	4.7
8. Zamyn Ud	4.0	3.8	4.3	5.4	5.2	4.0	3.9	3.2	3.7	3.6	3.5	3.4	3.7	5.0	3.7	3.6	3.6

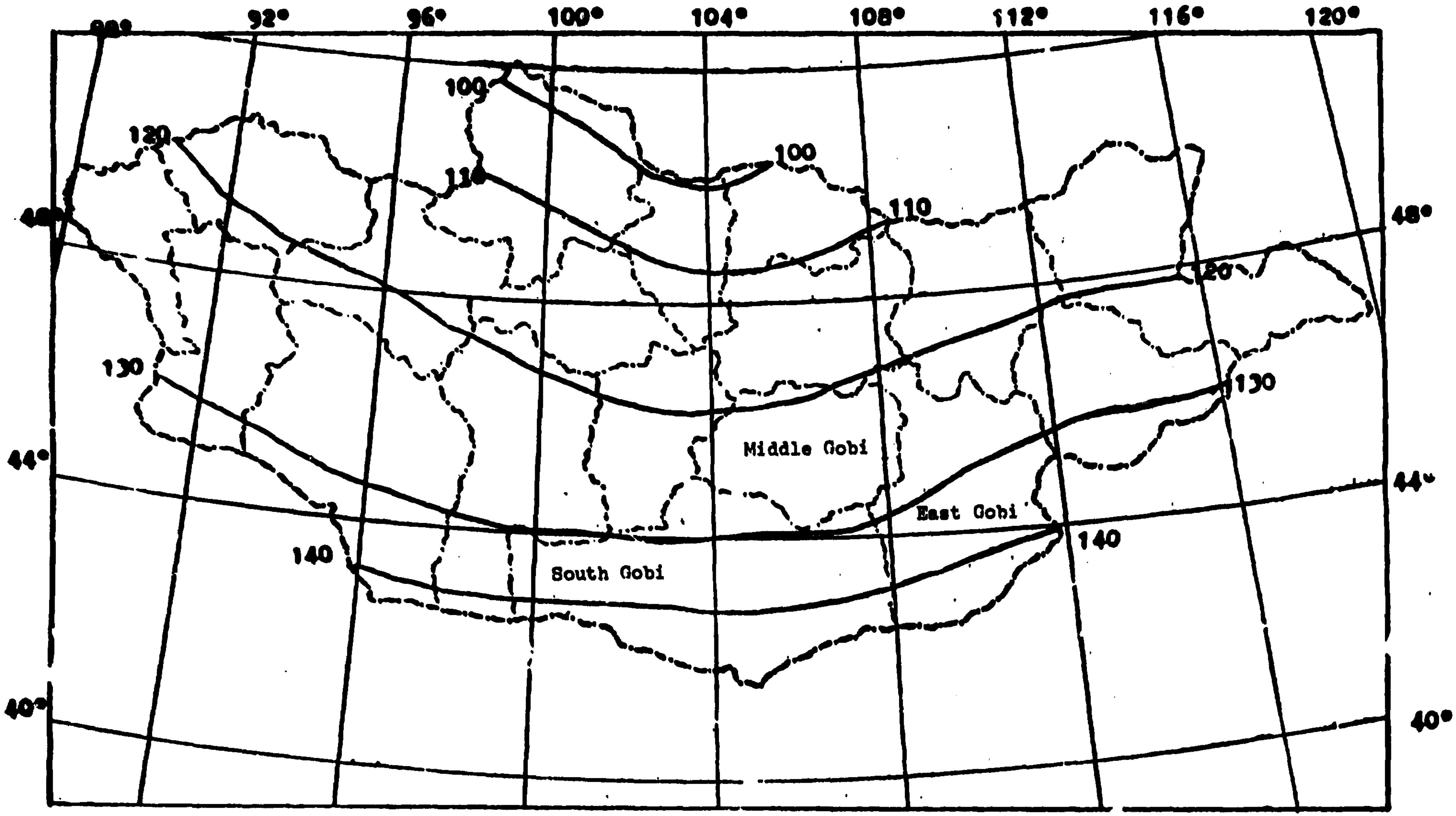
Table 2. Average data on the real duration of sun shining on Mongolia

	Meteorological station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
1.	Gurvan-tes	234	228	260	281	333	310	303	314	295	281	238	220	3 297
2.	Khövsgöl	214	217	243	256	300	310	314	307	281	272	220	212	3 146
3.	Dalan Zadgad	220	211	241	247	313	306	302	278	276	266	225	215	3 200
4.	Saikhan	218	223	245	257	298	306	303	300	295	269	221	208	3 143
5.	Sainshand	210	217	262	258	298	308	302	297	278	258	213	198	3 099
6.	Tooroi	210	218	245	270	318	289	304	314	276	262	210	187	3 103
7.	Bayandelger	208	222	271	275	296	312	314	256	270	242	208	194	3 068
8.	Mandalgov	213	226	269	264	303	288	290	292	276	260	218	203	3 092
9.	Baitag	208	215	266	281	307	298	293	300	290	256	219	175	3 108
10.	Tonkhil	205	208	244	253	293	283	276	266	259	246	210	197	2 940
11.	Altai	208	205	244	254	308	290	294	300	272	251	202	188	3 016
12.	Baruun-Urt	196	209	261	264	290	299	310	289	252	233	200	179	2 982
13.	Bayankhongor	220	224	259	250	323	301	293	299	278	260	220	206	3 011
14.	Khuzhirt	202	214	260	248	284	275	267	262	254	243	196	179	2 884
15.	Tsetserpleg	197	216	245	258	276	295	279	291	250	232	187	178	2 904
16.	Khalkh gol	191	210	263	260	289	300	290	280	257	230	181	170	2 922

Table 3. Data on the number of cloudy days in Mongolia

	Meteorological station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year Number	%
1.	Gurvan-tes	0.8	0.8	1.2	0.8	0.8	0.8	0.4	0.6	0.6	0.8	0.6	0.3	8.5	2
2.	Khövsgöl	1.5	1.2	0.8	1.3	1.3	1.3	1.5	0.7	0.6	2.2	0.8	0.8	14.0	4
3.	Dalan Zadgad	1.1	0.6	1.6	3.0	1.2	0.6	0.2	0.6	0.3	0.4	0.6	0.6	10.8	3
4.	Saikhan	1.1	1.0	1.4	1.0	1.0	0.8	0.2	0.9	0.2	0.5	0.9	1.2	10.2	3
5.	Sainshand	0.9	0.9	0.9	1.0	1.1	1.1	0.6	0.0	0.9	0.2	0.9	1.0	9.8	3
6.	Tooroi	1.1	1.2	1.5	1.0	0.5	0.8	0.6	0.3	0.0	0.0	0.2	1.6	8.8	2
7.	Bayandelger	1.0	0.8	0.6	0.8	1.0	0.2	0.6	0.8	0.8	1.8	1.3	1.8	11.5	3
8.	Mandalgov	0.9	0.7	1.1	1.4	0.5	0.8	1.2	0.7	0.6	0.7	1.1	1.0	10.7	3
9.	Baitag	0.8	0.8	0.9	0.8	0.0	0.9	0.7	0.8	0.8	0.8	1.7	1.8	10.8	3
10.	Tonkhil	0.1	0.7	0.5	0.6	0.6	0.2	0.1	0.6	0.1	0.0	0.2	0.7	4.4	1
11.	Altai	0.7	1.1	1.1	0.9	0.6	0.7	0.9	0.6	0.2	0.5	0.4	0.8	8.5	2
12.	Baruun-Urt	1.7	1.2	0.8	0.7	1.2	1.2	0.7	0.8	0.6	1.6	2.0	1.7	14.2	4
13.	Khuzhirt	0.8	0.8	1.0	1.3	1.0	1.9	1.0	1.1	0.8	1.0	1.0	1.6	12.3	3
14.	Bayankhongor	1.1	0.8	0.4	1.2	0.2	0.6	0.2	0.4	0.2	0.8	0.4	0.8	7.1	2
15.	Tsetserpleg	0.9	1.0	1.0	1.3	1.0	1.8	1.8	1.0	1.0	0.9	1.1	1.2	14.0	4
16.	Khalkh gol	1.0	1.3	0.8	1.8	1.1	0.2	0.4	1.1	0.8	1.8	2.1	2.6	15.0	4
17.	Zuun mod	0.6	1.0	0.6	1.6	0.4	0.8	1.0	0.8	0.6	0.8	0.8	2.0	11.0	3
18.	Uliastai	1.2	1.0	1.0	0.4	0.1	0.8	1.0	0.7	0.8	1.1	1.6	2.0	11.7	3

Figure I. Distribution of annual solar radiation in Mongolia (kcal/cm²)



II. ACTIVITIES

A. Work plan

The project activities were as follows:

(a) Analysing the use of wind energy for water supply and of solar energy for heating water and dwellings;

(b) Designing, constructing and introducing prototypes for: wind-driven water-pump aggregates; means of heating water and dwellings; and solar cells;

(c) Preparing equipment specifications;

(d) Preparing technical documentation for prototypes;

(e) Working out study programmes for training national personnel abroad in the field of:

(i) Solar energy application;

(ii) Application of computer in the design of prototypes;

(iii) Modes of prototypes production;

(iv) Semiconductor and solar cells production;

(f) Selecting nationals for fellowship training abroad;

(g) Preparing technical documentation for manufacturing wind-driven water-pump aggregates, solar cells, and solar devices for heating water and dwellings;

(h) Installing commissioning and putting the equipment into operation for testing wind-driven water-pump aggregates, solar cells, and solar devices;

(i) Testing prototypes of wind-driven water-pump aggregates in the field and under laboratory conditions;

(j) Testing prototypes of solar cells and solar devices for heating water and dwellings;

(k) Assisting in the finalizing of technical documentation on wind-driven water-pump aggregates, solar cells, and solar devices for heating water and dwellings;

(l) Elaborating recommendations for using the scientific investigations of Mongolia's research institutes in producing prototypes of wind-driven water-pump aggregates, solar cells, and solar devices for heating water and dwellings.

B. Activities and results

The following activities were carried out:

(a) In July 1983, Mr. Bat-Erdene was appointed national project director and local personnel were selected;

(b) Office and working accommodation was arranged at the premises of the SCST; at the MWE repair shop; at the Ministry of Agriculture (Institute of Stock Breeding's workshop); and at the IPT (heat physics and photovoltaic devices laboratories);

(c) The Institute of Stock Breeding provided assitance with: (i) the design and testing of the JSA-0.5 pump, as an extension of an earlier activity related to the establishment of a new Acrobati ("Mongolia" version), as the JSA-0.5 was found to be highly suitable for small-scale water supply in rural areas of Mongolia. A further aim of this activity was to prepare the ground for experimental, local manufacturing of similar small-scale wind-driven pumping systems; and (ii) the elaboration, design and testing of wind-energy aggregate XYY-1, with a view to providing the power supply needed for domestic electrical appliances as well as for television and radio sets with low energy consumption;

(d) Assistance was given to the MWE repair shop in the design and production of the TWN-CYO-0.5-2.0, which has a larger capacity than the JSA-0.5;

(e) Assistance was given to the IPT in developing solar-device prototypes for heating water and dwellings (heat physics laboratory) and solar cells (photovoltaic systems laboratory);

(f) The testing sites of the SCST at Ulan-Bator and of the MWE at somon Bajandelger and South Gobi ajmak were used for trials of wind-driven water pumps and other wind-energy systems. The testing site of the IPT heat physics laboratory was used for solar-powered systems for heating water and dwellings.

C. Detailed activities of the consultant

Between 30 March and 29 September 1984, the consultant assisted in:

(a) The preparation and revision of requisition forms for equipment, including controlling and measuring instruments and complex hardware;

(b) The elaboration of training programmes (in Finland, India and the USSR) for seven Mongolian specialists in the field of design, production and testing of wind-driven water-pump aggregates, solar devices for heating water and dwellings, and solar batteries;

(c) The analysis of technical documentation on the prototypes and the preparation of recommendations for improvements;

(d) The preparation of programmes for testing prototypes, including (i) programmes and methods of testing Mongolian-made wind-driven water pumps (TWN-CYO-0.5-2.0 and JSA-0.5) and wind-energy aggregates (XYY-1) and (ii) programmes for testing a complex pilot system for the use of solar energy to meet the heating needs of consumers living under severe climatic conditions (approved by the SCTC and the Academy of Science);

(e) The preliminary testing of pilot prototypes of wind-energy aggregates and solar units;

(f) The installation and operation of elements of equipment received;

(g) The preparation of drafts of two project documents describing the application of computer hardware and software to strengthen the National Centre of Scientific and Technological Information, and the use of these computers for the design, production and testing of prototypes;

(h) The drafting of IPT projects;

(i) The analysis of the prototypes' characteristics made on the basis of comparison with foreign analogues and data from industrial catalogues and patents;

(j) The elaboration of proposals for the second phase of the project (draft project document subsequently approved by the SCST and submitted to the Resident Representative in Mongolia);

(k) The analysis of wind and solar energy resources that could be used to supply water and to heat water and dwellings (figure II).

D. Pilot prototypes

The first Mongolian pilot prototypes were three TWM-C40-0.5-2.0 pumps. The basic technical characteristics are: (a) wind turbine diameter - 2 m; (b) number of blades - 12; (c) type of wind turbine - low-speed; (d) revolutions per minute at a wind speed of 8 m/s - 80; (e) capacity of pump at various elevations - 0.5 m^3/hour (30 m), 1.2 m^3/hour (20 m), and 2.0 m^3/hour (10 m); (f) range of working wind speeds - 3-5 m/s; (g) total weight - 400 kg; (h) estimated price - 5,000 tughriks.

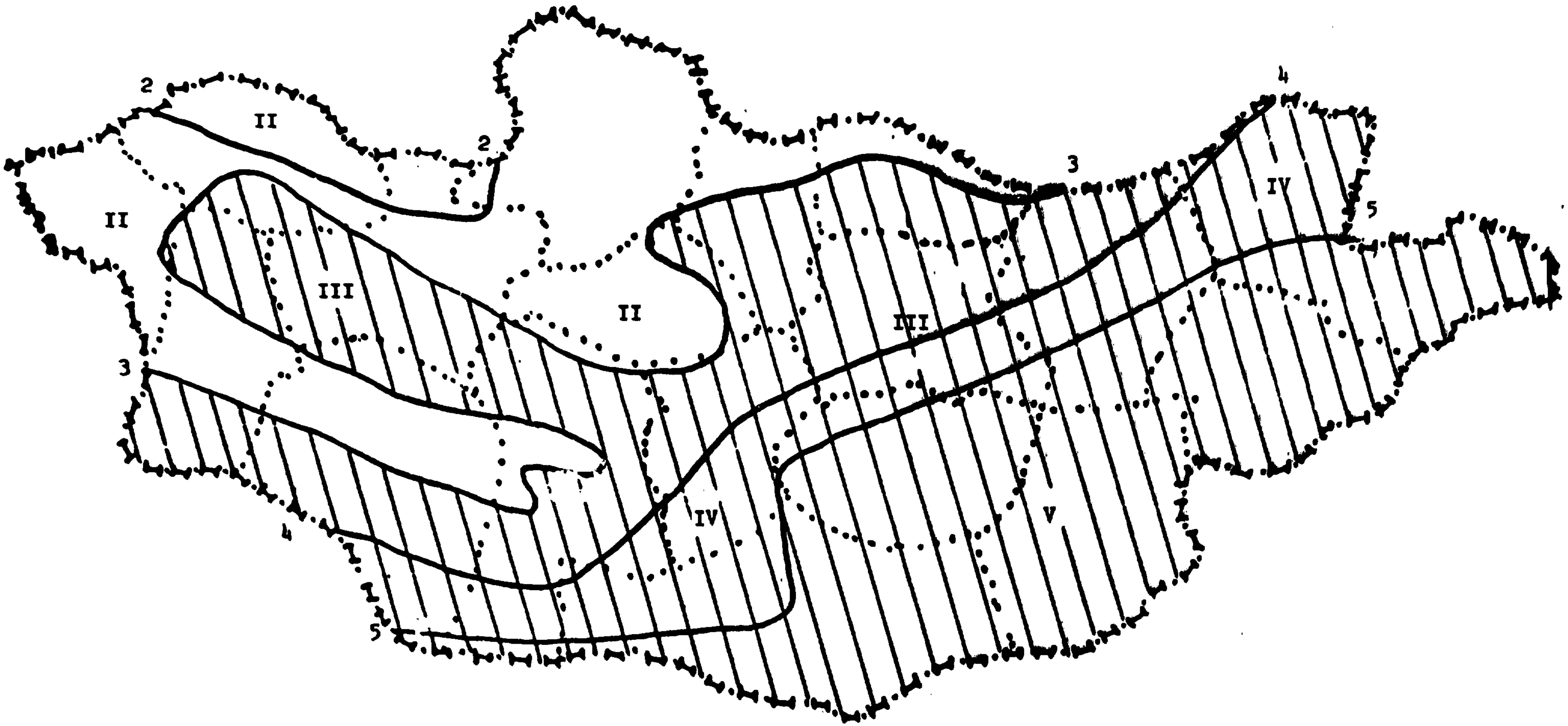
The basic characteristics of the pilot prototype for the small, JSA-0.5 pump elaborated by the Livestock Research Institute on the basis of the work of S. Jamjansharav, are: (a) wind turbine diameter - 1.2 m; (b) number of blades - 6; (c) type of wind turbine - low-speed; (d) revolutions per minute at a wind speed of 8 m/s - 150-160; (e) capacity of pump at 10 m - 0.5 m^3/hour; (f) total maximum elevation - 15 m; (g) range of useful working wind speeds - 2-15 m/s; (h) total weight - 30 kg; (i) estimated price - 1,500-1,600 tughriks.

Both models have piston pumps and storm-save systems in which the rotor turns sideways to the wind. The pilot prototype of the XYY-1 aggregate elaborated by the Livestock Research Institute, has a wind turbine diameter of 2 m and two blades. The capacity is 0.25 kW at a wind speed of 8 m/s.

Prototypes of devices for heating water and dwellings were established at the IPT experimental base. The principal scheme for a complex solar water heating system is shown in figure III. This system includes a collector subsystem, a heat-accumulating subsystem and a dubbing subsystem. The characteristics of the collector subsystem are: (a) summary square of two loop collector panels - 20 m^2; (b) gabarit sizes of one module - 1.55 x 0.25 x 0.92 m; (c) weight of one module (dry) - 30 kg; (d) heat carrier (water, antifreeze); (e) weight of heat carrier in panel - 1 kg; (f) maximum temperature in panel - 170 °C; (g) window pane for transparent insulation; (h) thickness of transparent insulation - 0.003 m; (i) thickness of heat insulation - 0.05 m.

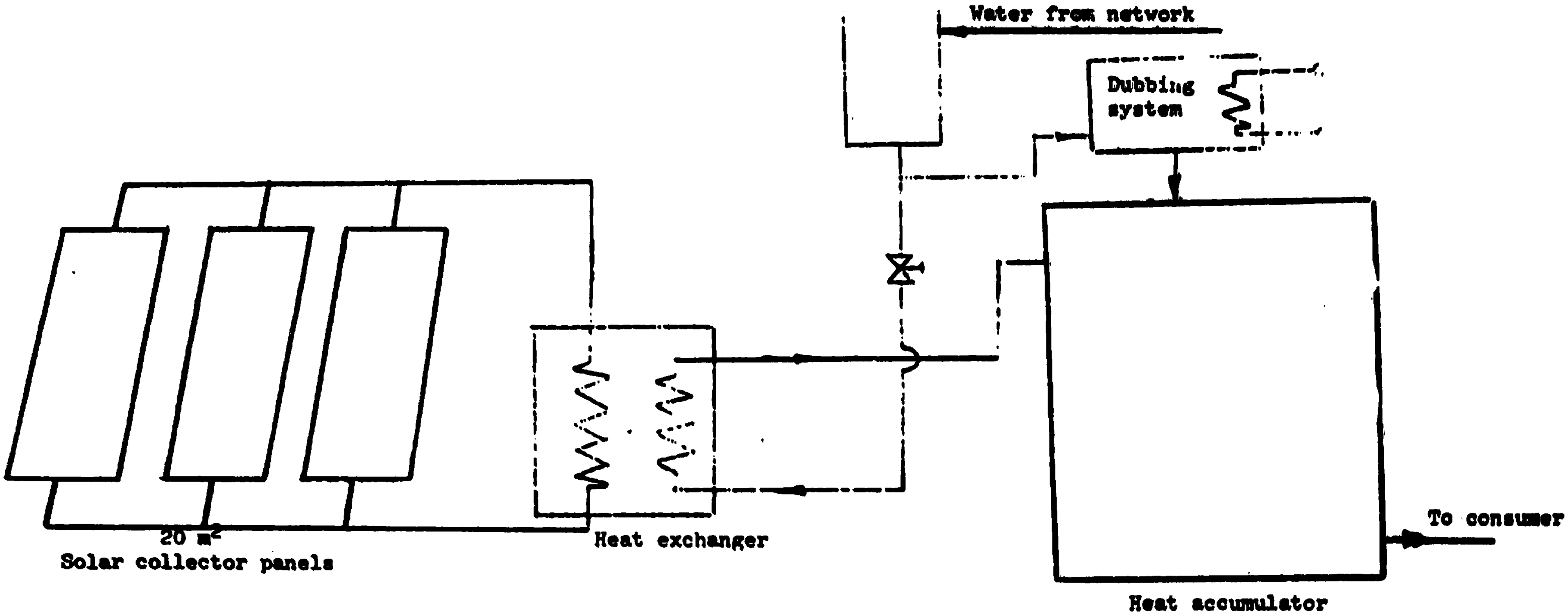
The characteristics of the heat-accumulating subsystem are: (a) volume of heat exchange tank - 200 l; (b) volume of accumulator tank - 300 l; (c) material of tanks - steel; (d) heat insulation material - wool, thick felt; (e) thickness of heat insulation - 10 cm; (f) staying power of accumulator

Figure II. Annual average wind-speed bands over Mongolia



Key: Suitable area of Mongolia for using TWN-C40-0.5-2.0 and JSA-0.5 pumps and XYY-1 aggregates. Pilot prototypes were produced and tested in Mongolia.

Figure III. Solar water-heating scheme



tank at ambient temperature of -5 °C - 5 x 24 hours; (g) initial temperature required to charge accumulator tank to provide nominal staying power - 80 °C; (h) 24 hours overfall of t° of water in accumulator tank - 10 °C/day.

The characteristics of the dubbing subsystem are: (a) a heating stove (type of firing - wood; nominal capacity - 500 l/h; hourly expenditure of firing - 0.2-0.3 m^3/h; output temperature of water by nominal capacity - 75-85 °C; heating surface - 1.36 m^2) and (b) an electrical heater (diameter of tube - 25 mm; consumption of electric current - 5.0 kW/h; nominal capacity - 600 l/h; temperature of water by nominal capacity - 75-80 °C; material of tube - zinc-coated iron).

A schematic diagram of a prototype of an experimental complex solar air-heating system, elaborated by IPT, is presented in figure IV. The characteristics of this prototype are: (a) a collector panel (gabarit size of one module - 1 x 1 x 0.25; summary square of collector panel - 20 m^2; heat carrier - air; window pane for transparent insulation material, with double glazing; distance between panes - 0.03 m; thickness of heat insulation - 0.1 m) and (b) a heat accumulating subsystem (volume of heat accumulating material - 1 m^3; type of accumulator material - gravel; heat insulation material - wool, thick felt, glass-paper; thickness of heat insulation - 0-25 cm).

The dubbing system is calculated to function from 1 to 3 hours during 24 hours to maintain an appropriate temperature (25 °C) for the heat accumulator in winter. In accordance with the work plan of the project, the technology of production of solar elements was elaborated at the IPT. Pilot prototypes of solar elements from monocrystal silicon have an efficiency of 9.5 per cent. Work is currently under way to increase the efficiency of these elements to 11-12 per cent for monocrystal silicon and to 6-7 per cent for tape silicon.

The pilot solar batteries were produced with capacities from 0.2 to 0.5 V as power supplies for portable radio receivers of type WEF, Sokol, Rossia. One with 6 V capacity was selected for production in Mongolia. A feasibility study was carried out with a view to establishing an experimental workshop that would produce 25,000 batteries per year. Figure V shows a principal application scheme for solar batteries to supply power for various consumer requirements (e.g. for portable radios and television sets). An evaluation of the potential fields of application of autonomous photovoltaic units in Mongolia is given in table 4.

Table 4. Main fields of application of autonomous photovoltaic systems for rural development in Mongolia

Maximum capacity (W)	Field of application	Demands (mW)	
		World demand	Mongolia
0.1-20	Radio and telecommunications	100	0.6
0.1-125	Agricultural equipment and instruments	7	0.2
5-10	Television sets	600	3
10-40	Lighting	600	4

continued

Table 4 (continued)

Maximum capacity (W)	Field of application	Demands (mW)	
		World demand	Mongolia
10-500	Drying, sterilization and storage of food	3 000	3
50-500	Water refining	350	0.3
10-500	Medical equipment	20	0.1
40-1,000	Water pumps for water supply	25 000	10
10-1,000	Nature reserves	30	0.5
10-10,000	Combined systems for electricity and heat supply	1 000	5
	Total	130 707	49.7

E. Technical documentation

Preliminary technical documentation elaborated at research institutes and workshops included the following:

(a) Technical requirements for TWN-CY-0.5-2.0 pumps (MWE workshop);

(b) Technical requirements for JSA-0.5 pumps (Institute of Stockbreeding);

(c) Technical requirements for solar devices for heating water and dwellings (IPT);

(d) Documentation based on a feasibility study for the establishment of a scientific unit for manufacturing solar elements (IPT);

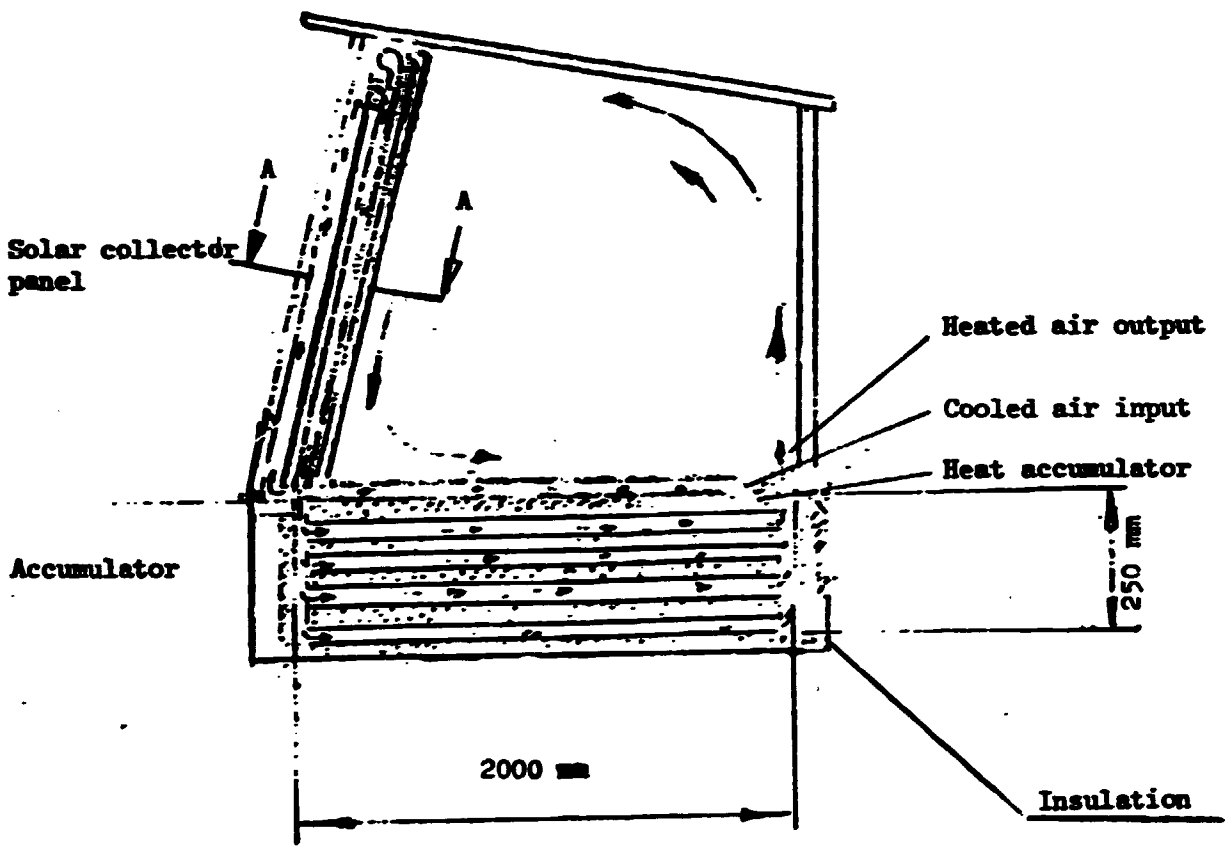
(e) Documentation based on a feasibility study for the establishment of an experimental technological base for manufacturing pilot prototypes (joint project on bilateral co-operation between the SCST and the Novosibirsk division of the All-Union State Design and Scientific Research Institute of the Academy of Sciences of the USSR);

(f) Documentation for "solar houses", "green houses" and solar baths (IPT in co-operation with the State Design Institute);

(g) Working drawings for the production of TWN-C40-0.5-2.0 (MWE).

The final technical documentation for pilot prototypes must cover: the technical tasks and conditions pertinent to manufacturing plants; the technology of production; installing and exploiting wind and solar energy units; and the adaptation and application of wind-driven pumping systems to water sources, prepared on the basis of project solutions suggested by other design organizations such as the State Research Design Institute of Water Supply of

Figure IV. Schematic diagram of prototype of an experimental complex solar air-heating system



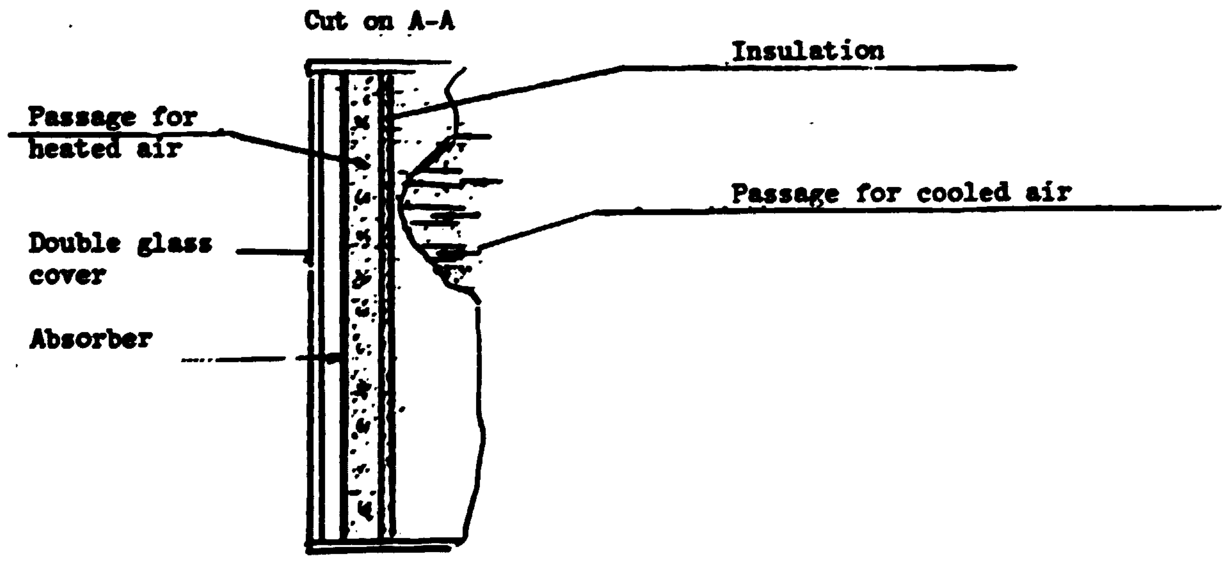
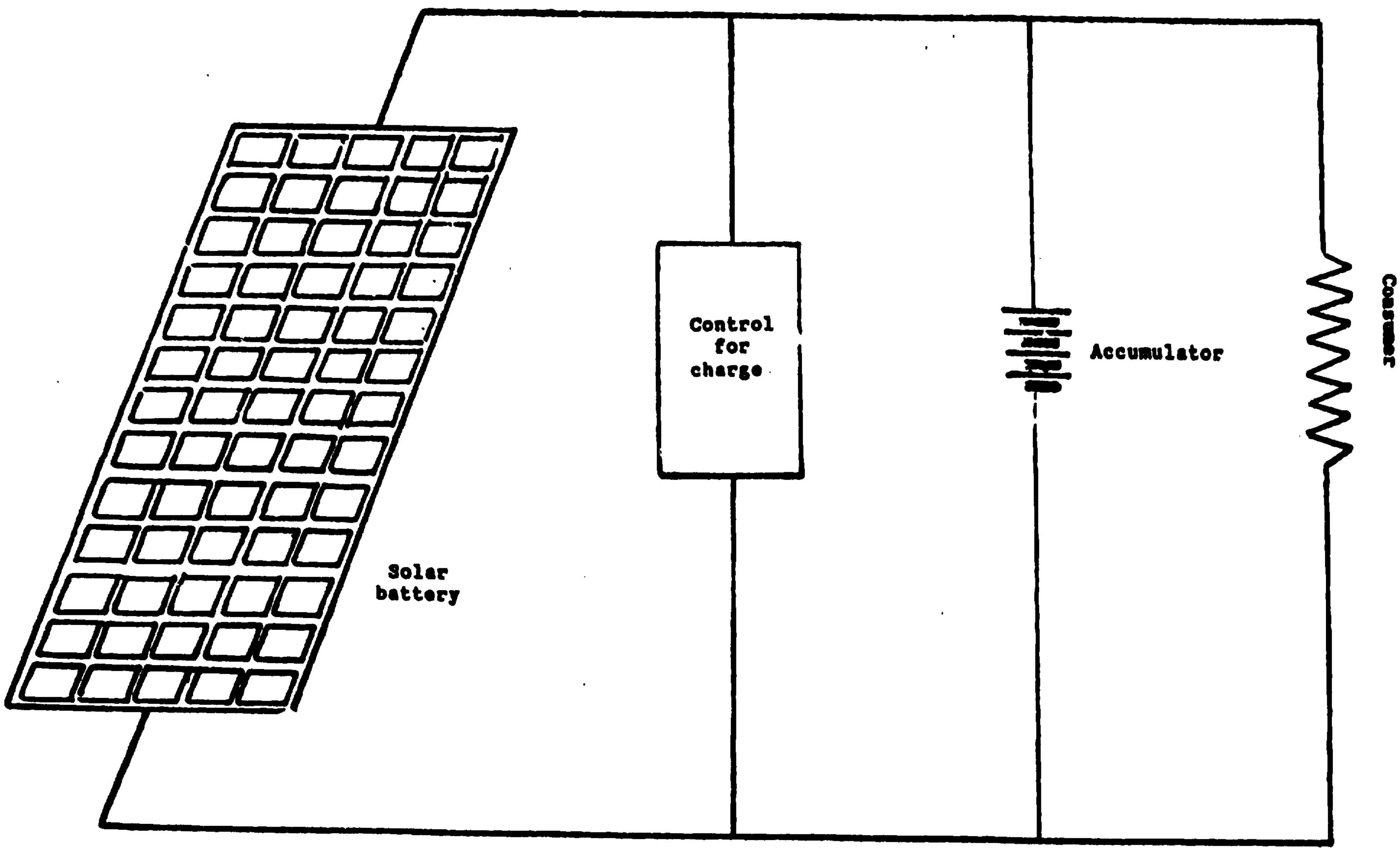


Figure V. Principal application scheme of solar batteries



the USSR. The final documentation should also be drafted bearing in mind the complete set of standards of the United System of Constructor Documentation.

F. Training national personnel abroad

Training programmes were prepared for seven national specialists who will participate in the development of the technological base of the SCST. They cover:

(a) Technology and experience in the utilization of solar energy for improving living conditions. (Fellow: Mr. Losol Khaltay, chief of laboratory, IPT; one month at Ekosolar oy Bruno Erat arkkit and Design Film Arkins ay Helsinki);

(b) Application of computer techniques for pilot prototypes elaborated on the basis of scientific research. (Fellows: Mr. B. Jambimolom and Mr. Ganbaatar (scientific staff of SCST); one month each at Siberian Division, Academy of Sciences of the USSR, Novosibirsk);

(c) Organization of modern technology for the production of experimental prototypes. (Fellows: Mr. R. Baldanish and Mr. O. Ovgon (heads of MWE workshops); one month each divided between Siberian Division, Academy of Sciences of the USSR and All-Union Academy of Agriculture (experimental plants), Novosibirsk;

(d) Modern technology for production of semi-conductor materials and solar cells. (Fellows: Kh. Dorj and Mr. M. Baatarkhuu (scientific staff, IPT); one and a half months each divided between All-Union Institute of Electricity for Agriculture (Moscow), Armenian Helio Laboratory (Erevan), and Ashabad National Physical Laboratory (New Delhi).

G. Analysis of technology and equipment for local production of pilot prototypes

Local production of JSA-0.5 pumps is one of the simplest to carry out among the industrial projects proposed for Mongolia. Local manufacturing of these small pumps (like the Acrobatti) could be started with a small investment and existing equipment. Trial production of 150 units could be undertaken at the Livestock Research Institute. Standard Mongolian water tanks could be used, or concrete tanks could be made. Standard steel tanks from the MWE workshop could also be used. Industrial production could be started, for example, at the MWE workshop at Ulan-Bator with little investment. The same personnel and organizational apparatus should be involved in both trial and industrial production.

The Finnish-Mongolian Bilateral Co-operative Committee for Science and Technology agreed in late 1983, at Ulan-Bator, to begin trial production of small, wind-energy systems. The estimated costs of the programme are presented in the mission report on project MON/75/006, "Demonstration of new sources of energy in rural development". Implementation of this programme might, however, require financing through a joint-venture company.

The local production of TWN-CYO-0.5-2.0 could be started, with insignificant investment, at the MWE workshop. Manufacture would involve, mainly, the use of commonly available raw materials, accessories, tools and machines. Soviet steel, machines and tools, which are the most commonly used in Mongolia, should be used in the manufacture of the TWM-CYO-0.5-2.0. For the trial production of 20 units, Mongolia might seek United Nations assistance through that Organization's programmes for science and technology for development (second phase of the project). For industrial production, Mongolia might consider the possibility of using the technological base being designed by the Novosibirsk division of the State Research Design Institute of the Academy of Sciences of the USSR.

A survey of the IPT technological base shows that existing equipment is not adequate for the production of solar devices for heating water and dwellings. It would be necessary, therefore, to prepare a feasibility study on the question and to elaborate technical requirements for the local production of solar collectors, accumulators, and a dubbing system of solar devices for heating water, dwellings, baths, greenhouses etc. Subsequently, it would be useful to organize the manufacture of this equipment at the proposed technological base.

Existing equipment at IPT's Laboratory of Solids was used to produce pilot prototypes of solar elements and batteries. However, there is a bottleneck in the laboratory caused by the continued absence of equipment requisitioned in 1984. The feasibility study on establishing a scientific workshop for the local manufacturing of solar batteries was carried out. The preliminary project documentation includes basic data on the main technological processes involved in the manufacture of solar elements: chemical refining of silicon plates; diffusion for establishing p-n junctions; attaching a protective covering; chemical etching; establishing back contacts by means of vacuum dispersion; establishing front contacts; coating with a photo lacquer; fixing the photo lacquer; developing; etching; establishing anti-reflective coverings; and connecting the elements and installing them in the main body of the battery. The equipment for these processes was selected. It is estimated that 49 workers would be required for the local annual manufacture of 866,320 elements for 35,000 (6 V) solar batteries.

In accordance with the standards of the United System of Constructor Documentation, documentation for installing pilot prototypes, such as wind-energy stations, solar cells, and solar devices for heating water and houses, should be included in the final technical documentation for the corresponding prototypes. This documentation is being elaborated, as well as instructions for installing wind-driven water pumps. With regard to the installation of pilot prototypes of TWM-C40-0.5-2.0 pumps: the first Mongolian TWM-C40-0.5-2.0 has been installed at Somon Bajandelger (figure VI); the second has been installed at the test site in South-Gobi ajmak; the third has been installed at the MWE workshop, where the prototypes were produced.

The first prototypes of the JSA-0.5 pump have been installed at the SCST test site at Ulan-Bator. The IYY-1 prototypes have been installed at the SCST test site at Ulan-Bator. The pilot prototypes of solar collector for water and air heating have been installed at the IPT test site (Academy of Science). The first Mongolian solar electric batteries have been produced and submitted for testing at the IPT Laboratory of Solid Physics.

H. Testing the pilot prototypes

The following instruments (provided as part of the project) were used to measure windspeed (in metres per second): a set of anemometer with digital display and counter, produced by the Leningrad Plant for Gidrometeopribor (USSR); hand-held digital anemometers provided by Northumbrian Energy Workshop (United Kingdom); and wind-speed indicators, supplied by Dwyer Instruments Inc. (United States). Pumping capacity was measured by running water into a

Figure VI. The first Mongolian wind-driven water pump (TWN-C40-0.5-2.0) at somon Bajandelger

measuring container while a wind gauge measured average wind speed. In this way, the correlation between pump production and wind speed was reached. After processing this experimental data, the following could be found: wind speed; average wind speed over a given period; maximum wind speed; pumping capacity (power capacity); maximum pumping capacity; and total pumping capacity (total power).

The programme and methods of testing TWN-C40-0.5-2.0 and JSA-0.5 pumps and XYY-1 aggregates, made in Mongolia, were elaborated by a UNIDO expert in co-operation with staff from the Livestock Research Institute (Mr. S. Jamjansharav) and the MWE (Mr. Baldan-Ish). Because the tests were conducted under field conditions, most measurements (which were performed at Bajandelger) were based on reliable, visual observation and the use of water containers, clock and wind gauges.

The measured results corresponded to the values given by the manufacturer. However, further testing would be needed in order to obtain readings reflecting the severe autumn and winter seasons. This is especially important in the case of wind-driven water pumps because wells freeze (figure VII).

Testing of the experimental solar heating devices was performed, in accordance with the "Programme for testing experimental-typical-complex systems for utilization of solar energy to meet needs of low potential heat consumers in MPR", with the assistance of a UNIDO expert on testing and the IPT Heat Physics Laboratory. The instruments used to measure sunshine were used also for testing the pilot prototypes for heating water and dwellings.

Experimental solar units with power capacity 0.5-10 V were tested in accordance with standard criteria used by the countries members of the Council for Mutual Economic Assistance. The tested solar units with capacity 0.2-0.5 V provided sufficient power for radio receivers of types VEF, Bokol, Rossia. The solar batteries with capacities of 10 V provided a power supply sufficient for lighting lamps.

I. Finalizing of technical and project documentation on pilot prototypes

Assistance rendered in finalizing technical documentation on pilot prototypes included:

(a) Recommendations on the improvement of TWN-C40-0.5-2.0 pumps with a view to their use under winter conditions;

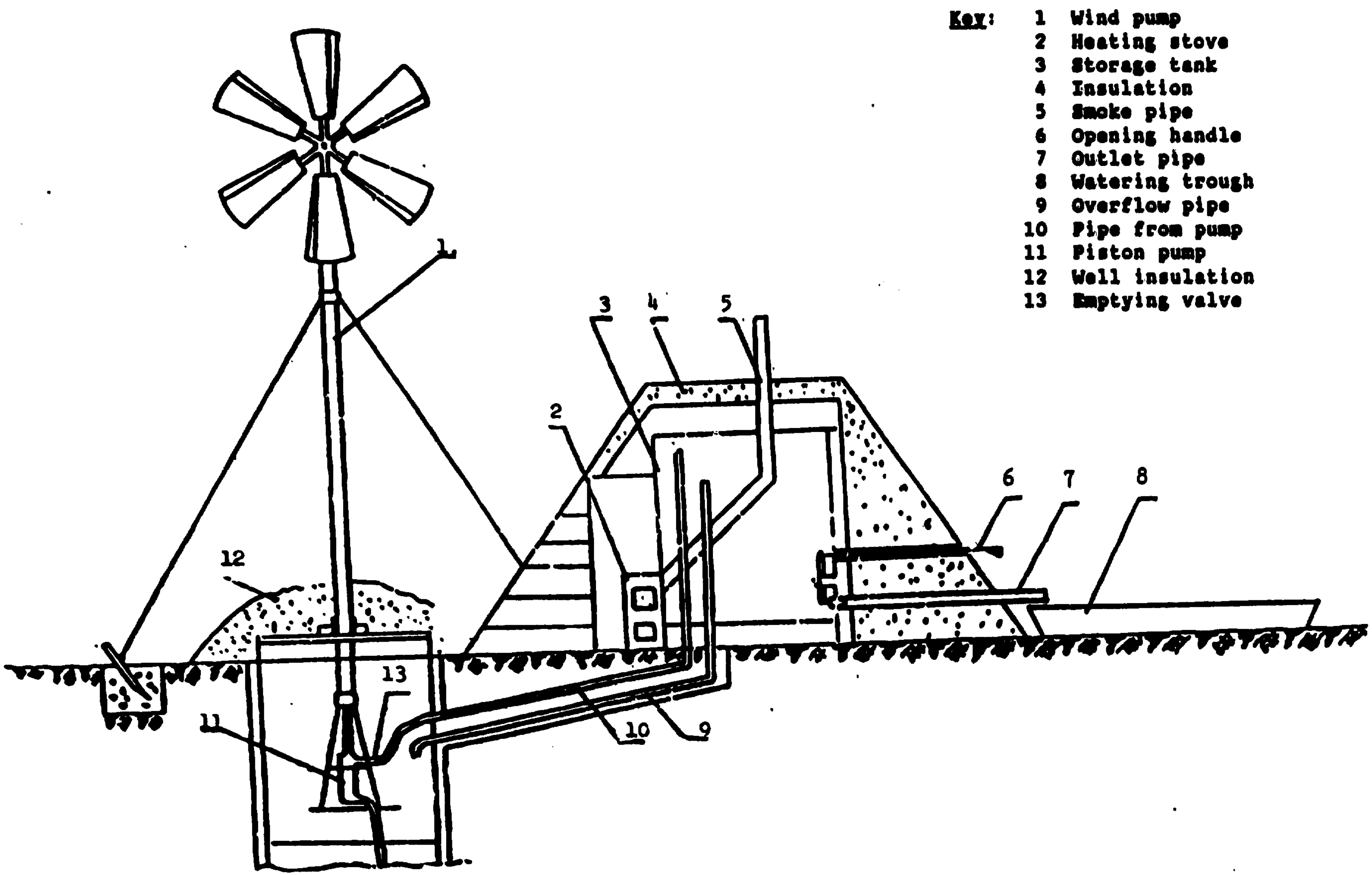
(b) Recommendations on the application of existing project solutions when installing wind-driven pumps at water points;

(c) Preparation of a project document on the development of photovoltaic technology at IPT;

(d) Preparation of project documentation on the development of helio-heating technology specific to conditions in Mongolia;

(e) Recommendations on the choice of equipment for plants for the local manufacture of devices for, in particular, wind-driven water pumps and solar units.

Figure VII. Proposal for an animal watering point for winter conditions



III. ACHIEVEMENT OF IMMEDIATE OBJECTIVES

A. Establishing modern design and testing procedures for prototypes

On the basis of scientific and technological research, proposals were formulated for the establishment of pilot prototypes, including:

(a) A wind-driven water pump of type TWN-C40-0.5-2.0 (MWE Research Institute and workshop);

(b) A wind-driven water pump of type JSA-0.5 (research by Mr. Jamjansharav, Livestock Research Institute);

(c) Solar units for heating water and dwellings (research by Mr. Khaltay, IPT);

(d) Solar cells and batteries (research by the Laboratory of Solid Physics, IPT).

Modern design procedures were adopted for producing pilot prototypes, including the following basic stages:

(a) Elaboration of technical requirements (responsibility: research institute and customer);

(b) Elaboration of preliminary technical documentation (responsibility: Special Construction Bureau had to be established on recommendation by international consultants);

(c) Elaboration of final technical documentation (responsibility: Special Construction Bureau). (The preliminary and final project documentation is recommended in accordance with the requirements of the Standard on United System of Constructor Documentation as adopted in the USSR.);

(d) Production of first pilot prototypes at local institute workshops. (Future production to be at a special experimental plant being designed.)

B. Training a team of engineers in design analysis and the construction of prototypes

Arrangements were made for the further training abroad of seven Mongolian specialists. In addition, on-the-spot training of national personnel was conducted through:

(a) Consultations in the field on the technical requirements of pilot prototypes;

(b) Assistance in becoming acquainted with existing standards for constructor and design documentation and in choosing standards appropriate to local conditions;

(c) Consultations and seminars on the preliminary and final project documentation for TWN-C40-0.5-2.0 and JSA-0.5 pumps, XYY-1 aggregates, solar devices for heating water and houses, and solar elements and batteries;

(d) Consultations on modern prototype testing procedures and on the use of advanced instrumentation in measuring wind and solar energy;

(e) Consultations on advanced technological processes being used in the production of similar prototypes abroad;

(f) Workshops on international information services offering publications and catalogues on industrial equipment and scientific research work;

(g) Consultations on the application of computer hardware and software in data information processing;

(h) Workshops on the use of computer techniques in designing pilot prototypes and processing test results;

(i) Consultations on pilot prototypes on view at the "Invention and Rationalization-84" exhibition.

C. Creating an information system

It is planned to create a national information system (collection and retrieval) to link all activities related to the design, construction and testing of prototypes, particularly in the field of new and renewable sources of energy, within the Centre of Scientific and Technological Information (CSTI). The initial stage of the system has already been established. Other services will include the provision of data on industrial catalogues, publications and journals; scientific and research work; and patents. The order in which the various services are listed shows the sequence of the information system's projected development. In accordance with recommendations of the SCST, which is responsible for national information services, the development of a National Information System for Industrial Catalogues has been selected as the next stage. Through this system, research institutes and Government agencies involved in developing prototypes, in industrial planning and in developing the economy of Mongolia will be provided with data and background information on the equipment, research and scientific work required for preparing and implementing innovative industrial programmes.

D. Comprehensive programme for strengthening national capabilities in modern design and technological analysis

Proposals for strengthening national technological design and analysis capabilities include:

(a) Establishing an experimental design office (Constructor Bureau) for the elaboration of design and constructor documentation;

(b) Applying existing standards for constructor documentation, for example, those of the United System of Constructor Documentation;

(c) Establishing a unit for introducing, installing and mastering experimental prototypes;

(d) Establishing experimental units for the local production of test prototypes of TWM-0.5-0.2 and JSA-0.5 pumps; XYY-1 wind-energy aggregates; and solar devices for heating water and houses;

(e) Establishing a workshop on the local production of solar elements and batteries, in accordance with the preliminary technical documentation of the IPT (Academy of Science).

To realize these objectives, the project document for the second phase of the project, MON/81/T01, has been prepared in accordance with a protocol concerning $US 80,000 in assistance from the United Nations through its system for financing science and technology for development.

IV. UTILIZATION OF PROJECT RESULTS

Modern methods and measurement instruments were used to test the pilot prototypes of TWN-CYO-0.5+2.0 and JSA-0.5 pumps, XYY-1 wind-energy aggregates, solar devices for heating water and dwellings, solar elements and solar batteries. On the basis of the positive results from these tests, it was decided on local trial production of 150 JSA-0.5 pumps (to start in 1985) and 20 TWN-CYO-0.5+2.0 pumps (also to start in 1985). It was also decided to elaborate technical documentation for the local production of wind-driven water-pump aggregates, solar devices for water and air heating, solar cells and batteries.

The results from testing the TWN-CYO-0.5-2.0 pumps showed how improvements could be made to parts such as the piston pump, the pump fastening the bottom valve and the pump filter. Similar improvements were made on the JSA-0.5 pumps. A filter framework has been developed for these pumps, which prevents the bottom valve from touching the bottom during assembly. Moreover, filter material can be stretched around the framework to prevent tiny, foreign particles from getting into the pump. The installation instructions will stress that the filter framework must not touch the bottom. Spare-part kits for the pumps will contain a set of simple keys that will be sufficient for installing and repairing them and even for changing bearings worn out after several years of hard use.

Pilot prototypes of the TWN-CYO-0.5+2.0 are providing water to a pig-breeding farm at South-Gobi and a test site at Bajandelger. At the present time, the application of these, and JSA-0.5 pumps, is most feasible in the spring, summer and autumn. Winter use requires additional testing and the development of solutions to the problem of freezing wells. The MWE Research Institute, among others, is tackling this problem.

The positive test results from the first solar units for water- and air-heating also indicated where improvements could be made. The experience gained is being used to elaborate technical documentation for pilot solar houses, greenhouses and solar baths. Testing the first national pilot prototypes of solar elements and batteries provided an opportunity to investigate and improve national manufacturing technology and to upgrade the efficiency of solar elements from 9.5 to 13 per cent by 1986 for monocrystal silicon and from 3.5 to 7 per cent for tape silicon. The project recommendations regarding the local production of solar elements and batteries could be applied effectively if: (a) the equipment ordered earlier, but still outstanding, could be delivered as soon as possible; and (b) technical documentation were to be prepared detailing the local manufacture of solar elements with annual capacity of 150 kW (in accordance with the terms of the feasibility study).

V. FINDINGS

Agriculture, in particular livestock, is the most important branch of Mongolia's economy. It determines basic scientific research in the country, as well as the design, production and testing of the first prototypes in the country aimed at utilizing new and renewable sources of energy, including wind and solar energy. Analysis of water, solar and wind resources shows that Mongolia has favourable conditions for using wind and solar energy. The price of water taken from a low arat-made well by means of a small, wind-driven pump is calculated at 0.83-1.17 tughriks/m^3, taking an annual average wind speed of 3-4 m/s. This is less than any other calculated alternative in Mongolia. Using deep-bore wells and diesel-driven pumping stations, the price of one cubic metre of water is about three times as high.

Mobile photovoltaic systems, with capacities in the range of 0.2 to 10 V, are the most convenient and efficient power supply for radio receivers, television sets and lamps - all of which help to improve the living conditions of Mongolia's scattered, nomadic stockbreeders. To improve livestock breeding and the stockbreeders' living and working conditions, the first Mongolian prototypes were established within the framework of the project. These included: TWN-CYO-0.5+2.0 and JSA-0.5 pumps; XYY-1 wind-energy aggregates; solar devices for heating water and houses; and solar elements and batteries with capacities from 0.2 to 10 V.

The TWN-CYO-0.5+2.0 and JSA-0.5 pumps could be used in spring, summer and autumn. Winter use would require further improvements. The pumping devices remain unfrozen as long as well and water tanks do not freeze; however, they will break if the latter freeze. It is better, therefore, to start by using TWN-CYO-0.5+2.0 and JSA-0.5 pumps from spring to autumn in the south of the country and to develop, step-by-step, reliable systems for winter use in the north where temperatures can drop as low as -40 °C and ground frost is deep because there is little snow. Proposals have been developed in the MWE Research Institute, in co-operation with Soviet research institutes, to prevent vital water supplies from freezing. However, more research is needed in this area and on testing wind-driven pumps using some form of anti-freeze.

Test results of the first pilot solar units for heating water and houses show that the main subsystems (solar collectors, accumulators and dubbing devices) have a satisfactory capacity for work. Before practical application, however, these prototypes require additional testing (as part of testing on a 50 m^2 solar house that is currently being designed). A project document entitled "Strengthening technological base of heat-physic laboratory of Institute of Physic and Technology of the MPR for development of helio-energy technology in continental climatic conditions of the MPR" was elaborated to intensify this research and hasten its introduction into the economy.

The technology elaborated in IPT for manufacturing solar elements and solar batteries with 0.5+10 V capacity can be used in developing the local production of solar photovoltaic systems (in accordance with the feasibility study and preliminary project documentation). It requires, however, the supply of modern technological equipment and training in its use. The project document "Development of photovoltaic technology on the base of researches of the IPT" was prepared as the second phase of project MON/73/006, "Demonstration of new sources of energy in rural development", to provide the additional technical assistance needed from the United Nations.

The information system at the CSTI helped to find the data necessary to make appropriate technical decisions during the establishment phase of the pilot prototypes. The main feature of this system is that copies of original industrial catalogues, articles or reports, based on analysis of short, bibliographical descriptions compiled with the help of computers, can be supplied, as an additional service, to Mongolian consumers. Even now, copies of industrial catalogue originals exist on microfiche at CSTI.

The existing technological base at the Livestock Research Institute can be used for the trial production of 150 JSA-0.5 pumps. Likewise, the existing equipment and personnel at the MWE workshop can be used for the trial production of 20 TWN-CYO-0.5+2.0 pumps. Mongolian-made steel tanks with volume of 3 m^3 and a heating stove are suitable for both types of pumps. Industrial production of JSA-0.5 prototypes could be started in co-operation with the Finnish development company and with Soviet suppliers of steel tools and machines. Industrial production of TWN-CYO-0.5+2.0 pumps should preferably be established in co-operation with the Soviet Union as the technological base. Relevant designs are currently being developed by the Novosibirsk division of the All-Union State Design and Research Institute of the USSR.

Finally, the establishment of the first pilot prototypes has pointed to the necessity to strengthen national capabilities in modern design and technological analysis in order to realize the complete cycle: research > design > pilot prototypes > testing > local trial production > local industrial production.