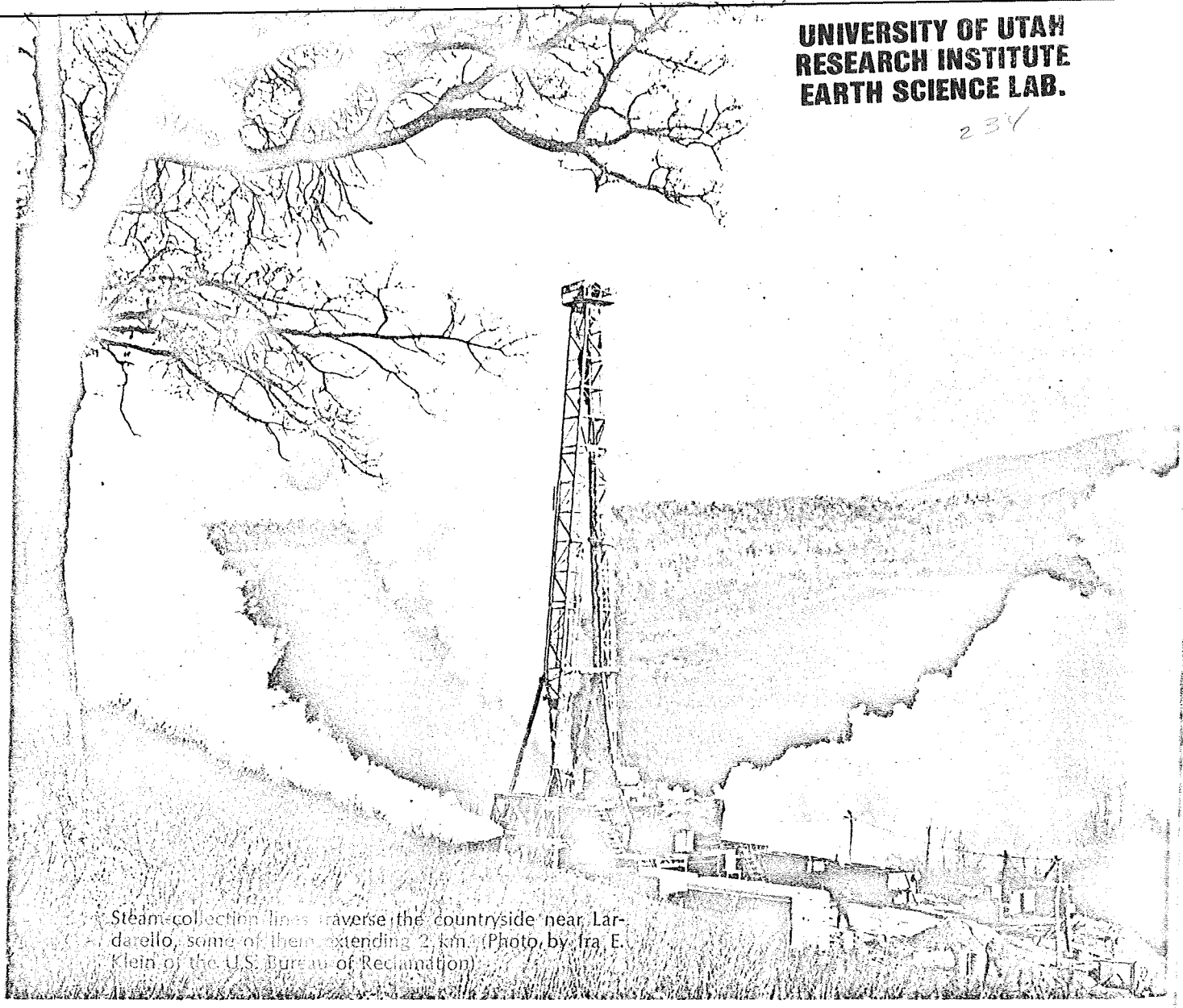

Steam-collection lines traverse the countryside near Larderello, some of them extending 2 km. (Photo by Ira E. Klein of the U.S. Bureau of Reclamation)

geothermal development

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MORE THAN 300 PERSONS, representing nearly 50 countries, took part Sept. 22/Oct. 1 in the United Nations Symposium on Development & Utilization of Geothermal Resources, in Pisa, Italy. The location was the School of Engineering at the University of Pisa.

The symposium was planned to bring together technical specialists in all phases of geothermal studies and representatives of emerging nations, to provide a total framework for the development of geothermal resources in underdeveloped countries. Therefore, the symposium was attended by Earth scientists, engineers, physicists and mathematicians, planners, economists, and administrators, as well as by United Nations functionaries.

There were 14 technical sessions, running consec tively. In addition, a 1-day field trip was provided to t Italian geothermal field at Larderello. There was overlap in program, and it was possible to participate every scheduled technical event. Therein, I believe, l the success of this symposium: the schedule was overly congested, and it was interdisciplinary. In t way Earth scientists were allowed, and almost co pelled, to mingle with economists, systems planners, utility executives, and to learn their problems and go For once, isotope specialists did not talk only to o isotope specialists. This also meant that each specia had to think carefully before he introduced his spec

vocabulary, if he wished to keep his audience.

Rather than list the topics of the 14 technical sessions, I will discuss briefly certain subjects that surfaced repeatedly, both in the formal sessions and in private discussions.

The theme of the symposium was sounded by Joseph Barnea (Director, Resources & Transport Division, United Nations): how can the specialized technical knowledge of the symposium participants be translated into the development of geothermal resources, especially in underdeveloped countries. Repeatedly, in questions from the floor, and in private discussions, Barnea urged that technical specialists use their scientific skills in solving problems of development. This met a mixed response. Several participants accused Barnea of promotionalism, and some others deplored his outspoken criticism of ivory-tower science. However, development was the theme of this conference, and our attention was continually returned to this subject whenever discussion became too academic.

Therefore, it is not surprising that the status of U.N.-sponsored geothermal resource projects was discussed at length. Ian W. Innes (New Zealand), who serves as project leader in Chile, described the difficulties of exploration at 14,000 ft elevation. Sveinn Einarsson (Iceland) discussed at length the program of re-injection of residual hot brines into the reservoir at Ahuachapan, El Salvador. This aroused appreciable attention. It was noted by Chester Budd (United States) that re-injection of steam condensates into the geothermal reservoir has been under way successfully for over a year at The Geysers, California. Several participants raised the question of cost of re-injection; this was not answered satisfactorily.

Accompanying the major theme of development ran the question of multiple use of geothermal resources.

Barnea urged that water desalination and industrial applications be developed along with power generation wherever possible. In Chile the desalination of brackish water may be attempted. Tsvi Meidav (United States) discussed the geothermal brines of the Imperial Valley of California as a target for desalination technology to accompany power generation. Ira E. Klein (United States) described activities of the Bureau of Reclamation in Imperial Valley. Further, Hans H. Werner (Canada) presented a paper on an improved technology for salt recovery from these geothermal brines. (It may be noted that the state of California has recently held a fact-finding hearing on the multiple-use potential of the Imperial Valley brines.) However, John J. C. Bradbury (United Nations) sharply questioned the economic feasibility of a multiple-use geothermal project. Bradbury noted that two uncertain technologies, desalination and geothermal power generation, would be combined in a high-risk venture. That would tend to double the possibility for failure, and would increase investor hesitancy.

Development of geothermal power in the 1960s did not fully meet the expectations of its early enthusiasts. The reasons for this failure are many, and vary from project to project. In general, early over-enthusiasm of proponents withered in the light of economic, technological, and often legal problems, to be replaced by excessive caution. The shortage of investor capital resulted in several aborted projects. Legal problems, especially in the United States, forced abandonment or delay of others. A lack of fundamental knowledge of geothermal systems, and a lack of trained investigators, has added to the delay. Now, however, these shortcomings are being corrected, slowly, and again there is optimism for the '70s. The United Nations is supporting 5 exploration projects; the United States AID program is deeply committed to another; and even the Swedish foreign-aid agency is exploring the feasibility of such an undertaking.

From data presented at the symposium, I have compiled the accompanying table of existing and proposed geothermal power stations.

Geothermal power generation to date depends on use of steam, and exploration has centered on discovery of dry-steam reservoirs. Where the reservoir fluid is in the liquid phase, as little as 5 to 10 per cent may flash to steam in boreholes. The remaining fluid becomes a disposal problem. Often this hot water is mineralized and potentially harmful. Schemes involving heat-exchanging between hot water and some other fluid with a low boiling point have been studied, especially in the Soviet Union and the United States. A newly designed system, using iso-butane as the heat exchanging medium, was described in the Rapporteur's Report on Section II, *Status of world geothermal development*. This system is to receive a commercial test in 1971-72 in the United States. If successful, it could radically change the course of geothermal exploration and spur development of lower-enthalpy hot-water systems for power generation.

Hot-water heating systems are widely used in Iceland, and are under development in Hungary and the Soviet Union.

For several years it has been customary to classify geothermal fields as yielding dry steam, hot water, or brine. Elaborate schemes have been developed, especially by Russian workers, to describe the genesis of thermal fluids of differing chemical composition. Other classifications have been made on the basis of the geologic environments of geothermal fields. Rapporteurs Ezio Tongiorgi (Italy) and James R. McNitt (United States) attempted to summarize the thermodynamic and geologic characteristics of geothermal fields. These summaries were challenged repeatedly; no consensus was apparent.

Several speakers suggested that there exists a genetic relationship between dry-steam fields and brine or hot-water fields; and that drilling to greater depths at a dry-steam field such as The Geysers, California, might encounter brine or hot water. Experience in New Zealand and elsewhere has shown that the steam flash-off percentage may increase with continued production from a field. Wells initially yielding hot water have been 'dried up' to yield ultimately steam. Permeability, therefore, may be the most critical factor in determining which phases will be present in a heated environment. This relationship has been explored by Ian Donaldson and Russell James, of the Department of Scientific & Industrial Research, New Zealand. Donald E. White (U.S. Geological Survey) has proposed the terminology of water-dominated and vapor-dominated systems to express the variability of phase with time and with artificially induced changes, such as drilling into a thermal reservoir.

Steam issues from discharge pipes in a well being completed at Larderello. Drilling technology is much like that used in oil & gas fields. (Photo by ENEL, Italy)

The papers presented at the symposium are to be printed eventually in a new journal, *Geothermics*, published by the Instituto Internazionale per le Ricerche Geotermiche, Pisa, Italy. Volume 1 of this journal, 'The geology, geophysics and hydrogeology of the Monte Amiata geothermal fields', was presented to each registrant at the symposium.

The Italian Organizing Committee and the United Nations did an outstanding job in arranging this symposium. Simultaneous translation of technical sessions was provided in 4 languages, pre-prints of all papers were given to each participant, and the details of transportation and accommodation were well arranged. In addition, the registrants were wined and dined at several receptions, courtesy of the Italian Organizing Committee, the National Electric Energy Agency (ENEL), and the cities of Pisa and Lucca.

Country, field	1969 Capacity, kw	Planned or under construction, kw	Total projected kw
Chile			
El Tatio	0	20,000	20,000
El Salvador			
Ahuachapán	0	20,000	20,000
French West Indies			
Guadeloupe	0	30,000	30,000
Iceland			
Namafjall	0	3,000	
Hveragerdi	17,000	0	20,000
Italy			
Larderello	365,000	up to 50,000	~440,000
Monte Amiata	25,000		
Japan			
Matsukawa	20,000	7,000	
Onikobe	0	tens of thousands	> 50,000
Otake	13,000	0	
Hachimantai	0	10,000	
Mexico			
Pathé	3,500	0	
Cerro Prieto	0	75,000	78,500
New Zealand			
Wairakei	160,000	not known	
Kawerau	10,000		>170,000
Broadlands	0	tens of thousands	
Philippines			
Legaspi	0	10,000	10,000
Taiwan			
Tatun	0	10,000	10,000
Turkey			
Kizildere	0	30,000	30,000
United States			
The Geysers	83,000	550,000	633,000
Brady's Hot Springs	0	10,000	
USSR			
Pauzhetsk	3,000	20,000	29,000
Kunashiry	0	6,000	