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## **The wave-power group at the Department of Physics, Norwegian University of Science and Technology NTNU.**

The research carried out by this group is aimed at serving as a base for the technical-industrial development w>

### **Transfer interrupted!**

energy of ocean waves may be utilised for commercial energy supply to a greater extent. Wave energy, which is a non-polluting and renewable source of energy, is created by natural conversion of part of the wind energy above the oceans. Wind energy is created by natural conversion of part of solar energy. With both of these energy conversions the flow of energy is concentrated (as figured in watts per square metre of area). Just below the ocean's water surface the wave energy flow, in time-average, is typically five times denser than the wind energy flow 20 m above the sea surface, and 10 to 30 times denser than the solar energy flow. Hence, there are good prospects for development of commercial wave-power plants, which may in the future become significant components for providing energy to many coastal nations.

### **SHORT HISTORIC REVIEW:**

This research group has since 1973 investigated methods for utilisation of the energy of ocean waves. In December 1973 the university teacher ("førsteamanuens") Kjell Budal (1933-1989) initiated the wave energy research at the Department of Physics, Norwegian Institute of Technology NTH, University of Trondheim (after 1995: Norwegian University of Science and Technology NTNU). Johannes Falnes participated in the research from the beginning in 1973, and Per Magne Lillebekken from 1980. Six persons have completed the doctor degree ("dr.ing.") within the wave-power research at NTH, namely: Lars Christian Iversen in 1980, Åge Kyllingstad in 1982, Oddbjørn Malmo in 1984, Geirmund Oltedal in 1985, Arne Brendmo in 1995 and Håvard Eidsmoen in 1996. Moreover, 21 students have carried out their thesis work for completing the "sivilingeniør" degree. The wave-energy research carried out in Trondheim is of good reputation internationally. This is mainly due to basic theoretical research and, in particular, to proposed methods for optimum control and phase control of wave-energy converters. During the years 1978-82 wave-energy research received substantial financial support from the Norwegian Ministry of Petroleum and Energy ("Olje- og energidepartementet"). As the price of petroleum decreased and the public interest for problems of environment and resources decreased during the early 1980s, the governmental financial support of wave-power research was drastically reduced after 1982. In spite of this fact the wave-power group has been able to carry on a certain research activity and maintenance of achieved knowledge and competence. From 1994 the group has cooperated with the company Brødrene Langset AS, from 1998 with the new-established company ConWEC AS, on developing an optimally controlled wave-power converter. Among the mentioned persons, two are still in daily work at the Department of Physics, namely Johannes Falnes (Professor, "dr.techn.") and Per Magne Lillebekken (Technical Manager, "sivilingeniør").

### **TAUGHT COURSES ON WAVE ENERGY**

Wave energy is one of several subjects contained in the course Physics and Energy, which has been taught every year since 1974, when Jørgen Løvseth initiated the course, at the College of Arts and Science (AVH), University of Trondheim. part 2

A more advanced and theoretical course, Ocean Wave Energy, has been taught about every second year since 1979, when Johannes Falnes started to develop this "dr.-ing." course at the Norwegian Institute of Technology (NTH), University of Trondheim.

## REPORTS OG PUBLICATIONS

A separate list names the authors and titles of scientific papers, reports and other publications from the wave energy group at NTNU. Moreover, the following papers/reports are, in full version, placed on Internet:

J. Falnes: "Energj frå havbølger før, no og sidan." This (1996) note in Norwegian contains a historic review of wave power research, including a view towards the future. The note, which includes two figures, is aimed at non-specialist readers. At the end of the note there is a list which names the title of some books containing matter on wave energy.

J. Falnes: "Principles for capture of energy from ocean waves. Phase control and optimum oscillation." By referring to illustrations (six figures), but without using mathematics, this (1997) note explains the principle for absorption of wave energy by means of an oscillating system. It also explains how the system should oscillate in order to absorb as much energy as possible. During more than twenty years, these principles have directed much of the wave-energy research carried out at the university in Trondheim. The note, which includes 15 literature references, is aimed at non-specialist readers.

J. Falnes: "Prinsipp for opptak av energi frå havbølger. Fasestyring og optimal svingerørslø." Norwegian version of the same (1997) note.

J. Falnes: "Optimum control of oscillation of wave-energy converters". Paper no. 2 in Annex Report B1 to the JOULE project "Wave Energy Converters: Generic Technical Evaluation Study". Contract no. JOU2-0003-DK between the Commission of European Communities and Danish Wave Power aps. August 1993.

Since this publication is distributed in rather few copies, we have placed the paper on Internet. The paper, which presents a review of the research carried out during the twenty years after 1973 on optimum control of wave-power devices in order to maximise the power output, is aimed at specialist readers, although only a minimum of mathematics is used. The note does not include any illustrations, but 39 references.

H. Eidsmoen: "Simulation of a tight-moored amplitude-limited heaving-buoy wave energy converter with phase control". This rather long (1996) paper, which includes 12 figures, 7 tables, 28 references and 18 numbered and displayed mathematical formulae, is aimed at specialist readers. The paper represents an extension and enlargement of the following published work:

Eidsmoen, H.: "Simulation of a heaving-buoy wave energy converter with phase control". Proceedings of the Second European Wave Power Conference, (edited by Elliot, G. and Diamantaras, K.) Lisbon, Portugal, 8-10 November, 1995, European Commission ECSC-EC-EAEC, Brussels, pp 281-288, 1996. (ISBN 92-827-7492-9). A summary of this paper has been printed in Applied Ocean Research, Vol. 20, No. 3, 1998, pp. 157-161.

H. Eidsmoen: "Simulation of a slack-moored heaving-buoy wave energy converter with phase control". This rather long (1996) paper, which includes 10 figures, 13 tables, 34 references and 19 numbered and displayed mathematical formulae, is aimed at specialist readers.

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More information on research on ocean wave energy may be found on the [European Wave Energy Research Network](#).

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