

A Primer on New Alchemy's Solar Aquaculture

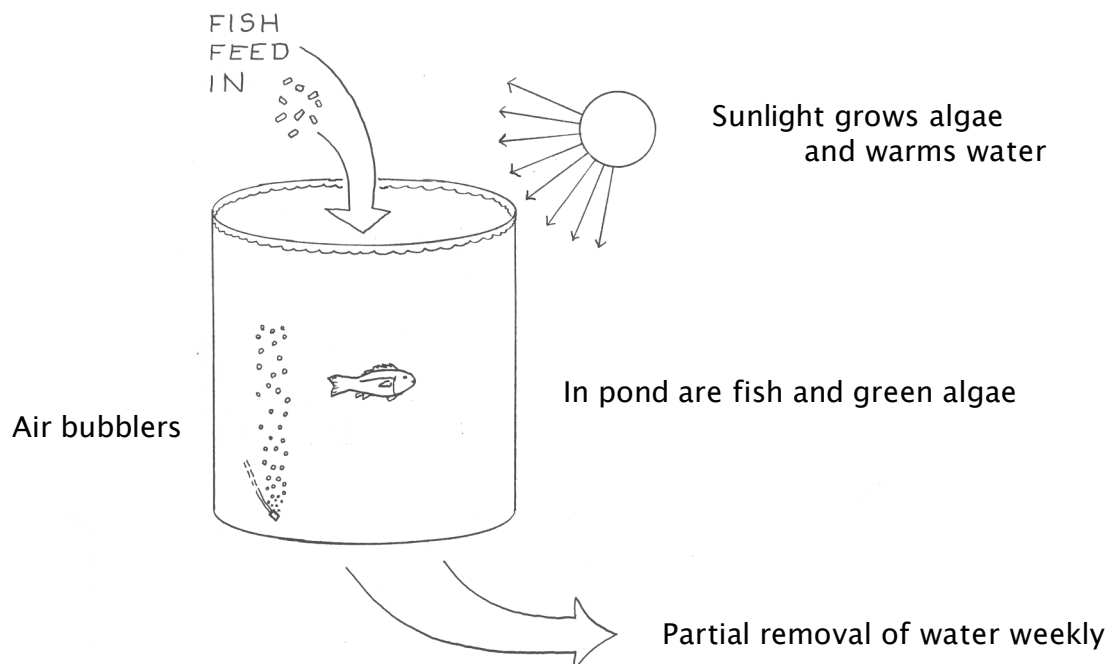
Earle Barnhart

Aquatic Alchemy

From 1971 to 1991 New Alchemy Institute researched the idea of growing edible fish on a household scale. The goal was to grow high-quality fish protein in a small, clean, controllable pond, using home-scale technology and minimum fossil fuels. After many years' inspired trial and error, backed up by meticulous science, there emerged techniques for fish culture in what New Alchemy called solar ponds— large cylinders of water for growing edible fish.

A standard New Alchemy solar pond is a 5' high, 5' diameter, translucent fiberglass cylinder that contains about 700 gallons of water. Typically each pond contains 10–20 pounds of fish that are fed daily at an optimum rate of 3% of their body weight. Managed for high production, such a pond can produce an annual growth of 40 pounds of fish. The solar pond should be located in full sunlight and has air bubblers continuously aerating it. Good management also includes removing 20% of its water each week, and then refilling with 20% fresh water.

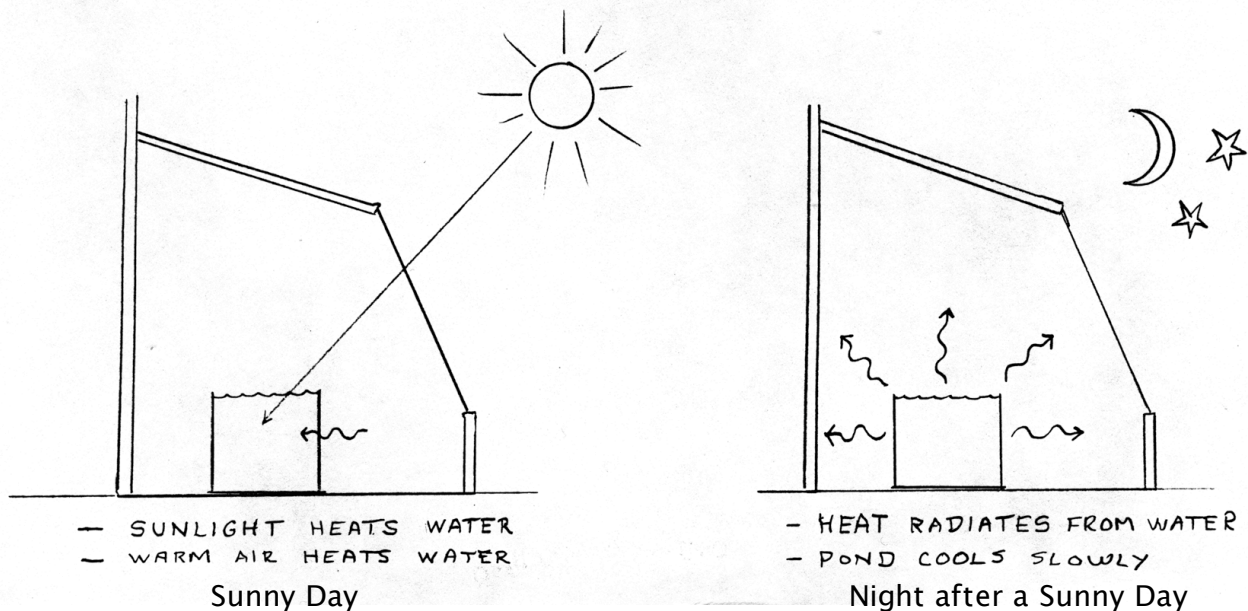
The biology and chemistry in the solar pond changes constantly. Each day the fish in the pond are fed. Some of the eaten food is absorbed as the fish grows, and some of it becomes wastes that mix in the water. Microscopic green algae live in the pond with the fish, and as they grow they absorb nutrients from the water. Each day sunlight strikes the pond, entering the water and helping the algae grow. Sunlight also causes the water to get warmer. Fish generally grow faster in warmer water.



Solar Ponds For Solar Heat Storage in Buildings

A solar pond can serve two purposes in a building or greenhouse – fish culture and storage of solar heat. Sunlight that strikes a solar pond enters the water and is initially absorbed by the dense, green algae in the water. As growing plants, the algae can capture about 5% of the solar energy. The other 95% of the solar energy becomes heat and makes the pond water warmer.

During each sunny day, the water in a solar pond warms up and stores heat. Each night the pond cools down as some of that heat is released into the air and is radiated to nearby objects. This storage and release moderates the extreme high and low temperatures in the greenhouse. Because some of the incoming sunlight is stored as warm water rather than hot air, the air is cooler during the day. Because the solar ponds release heat at night, the air is warmer during the night.



Solar heat storage and release in solar ponds is automatic. It occurs due to passive, natural movement of light, warm water and warm air. It does not require pumps or fans or controls. A solar pond can store an enormous amount of heat. It can sometimes provide useful heat for several nights in row as it slowly cools.

Solar heat from a solar pond can substitute for heating a greenhouse with gas, oil or wood or electricity. In mild temperate climates, solar ponds can largely eliminate the need to burn fossil fuel for heat. In the Cape Cod Ark, for example, in a region with many sunny winter days, the daytime temperatures are often tropical and the lowest night-time temperatures only occasionally approach freezing. The plants grow actively during the warm days and slow down each night.

In computer simulations of dome greenhouses, the presence of solar ponds as thermal mass reduces the average daily temperature swings by 10 degrees F, and raises the monthly minimum temperatures by 6-8 degrees F.

Understanding the Biology and Chemistry of Solar Aquaculture

For aquaculture research, solar ponds can be treated like very large test tubes. Two solar ponds can be placed side by side and tested against each other by treating one different than the other. Or 10 solar ponds can be tested at once, with 10 different treatments. The biological activity in each one will be different than the others, and the fish will be observed to grow faster or more efficiently in one than another.

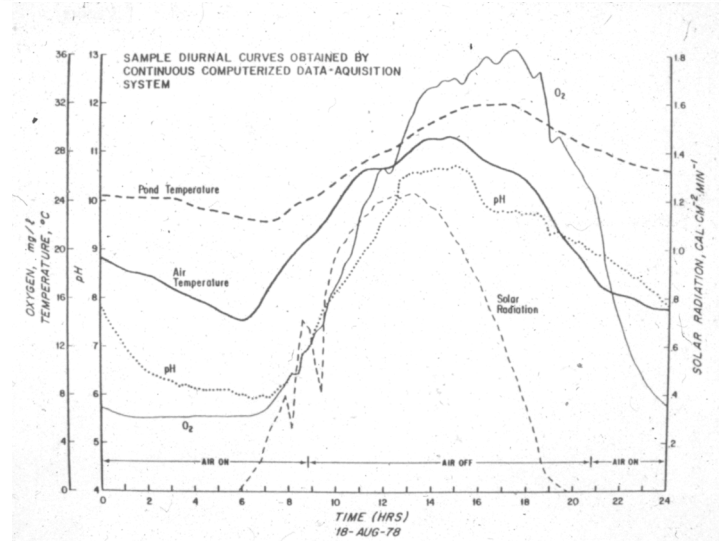
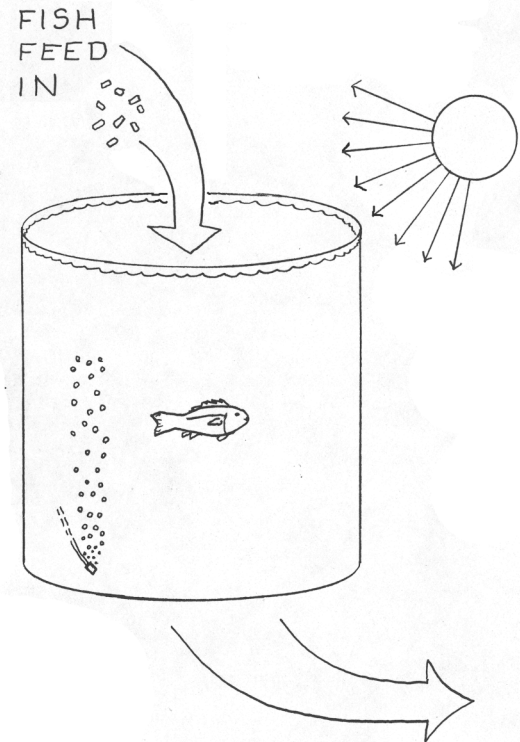
From 1974 to 1986, New Alchemy used this test tube approach with the aim of learning how to grow fish for human food

Experiments were done with different kinds of fish, numbers and sizes of fish, types of fish feeds, rates of feeding, methods of aerating, amounts of reflected sunlight, and a myriad other factors,

The simplest variables to test are the fish in the pond (type, size, number), and the kinds and amounts of fish food fed to the fish. Other variables that can be controlled are rates of aeration, rates of harvest of fish, and periodic adding of fresh water.

Other important variables are not so easy to control, such as the amount of sunlight each day. The aquatic ecosystem in a solar pond is greatly affected by sunlight. With more sunlight, the water gets warmer, biological activity increases, the algae make more oxygen and take up more carbon dioxide, and the water chemistry changes. All these things affect how well the fish grow.

Over a 24 hour period, the effects of sunlight on a solar pond reveals a daily cycle of warming and cooling and changes in oxygen and pH levels of the water. Sunny days show different patterns than cloudy days. And the fish grow at different rates, depending on their temperature and water chemistry.



Using Computer Models To Study Aquaculture

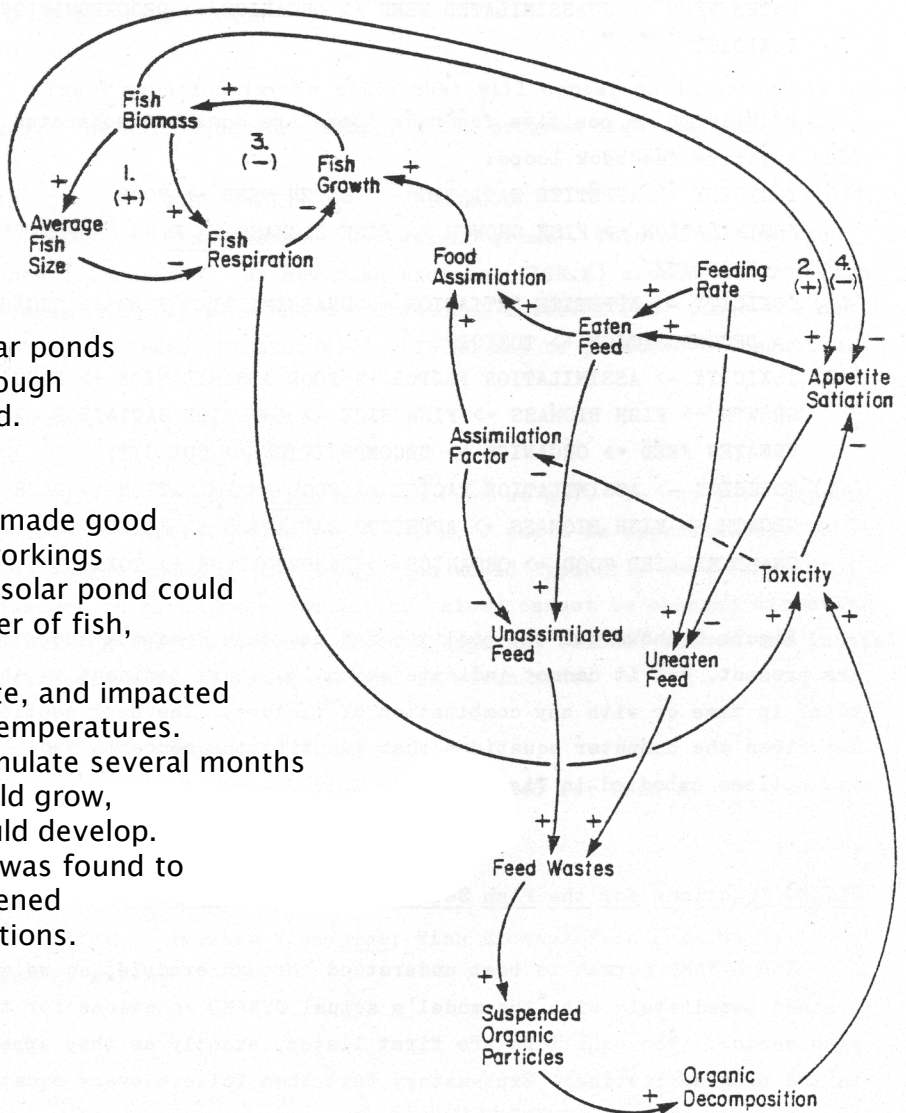
After years of careful observation, analysis, and diligent precise measurements, New Alchemy's aquaculturalists gained a detailed understanding of the processes in a solar pond. But the processes are astonishingly complex, and often involve a web of non-linear interactions that are too complex for a person's brain to calculate or predict.

So to refine their understanding of the thermodynamics and bioschemistry of the solar ponds, New Alchemy's researchers constructed a mathematical model of the interactions within a solar pond. The value of a modeling approach is that, if one can craft a model that is accurate in its rates and interactions, the model can be used in predictive ways to test how well a future pond might do if managed in a particular way.

They started with a simple model of the most obvious patterns of cause and effect. For example – adding fish food caused the fish to grow, but gradually accumulated wastes that slowed the growth down. Each cause and effect was entered into the model as a mathematical rate, that changed as temperature or oxygen or light levels changed.

The model was gradually improved and made more detailed, and was tested against reality by entering data from real solar ponds to see if the model was accurate enough to reproduce what actually happened.

Eventually the computer model was made good enough to accurately simulate the workings of real solar ponds. A hypothetical solar pond could be started with a certain number of fish, fed daily with a certain amount of fish feed, aerated at a certain rate, and impacted by typical patterns of sunlight and temperatures. The model could be set to run to simulate several months of time to see how well the fish would grow, and whether any bad conditions would develop. The computer model's virtual pond was found to closely resemble what actually happened to a real pond under the same conditions.

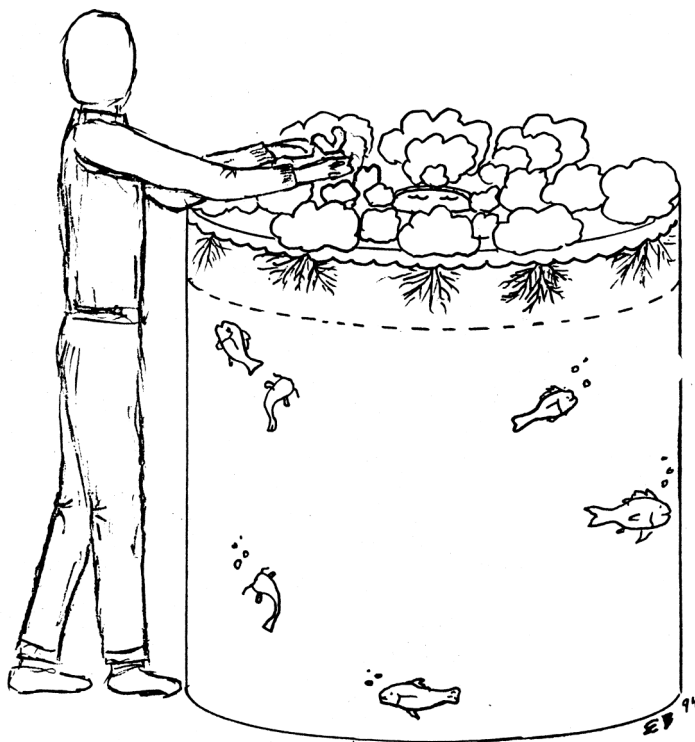


Hydroponics in Solar Ponds – The Zweig Pond



The most sophisticated version of aquaculture using solar ponds is the hydroponic solar pond, developed and refined by Ron Zweig. A Zweig pond is a solar pond with fish growing in the water and hydroponic lettuce growing floating on the surface. The fish are fed, and the lettuce plants get their nutrients from the fertile water of the fish pond. By removing waste nutrients from the water, the lettuce help purify the water and promote better growth of the fish.

The Zweig pond is that it produces lettuce continuously, in addition to periodic harvests of edible fish.



The lettuce roots are protected from being eaten by the fish by plastic mesh that separates them.

Small lettuce plants are started in the center of the pond and are moved outward toward the edge as they grow larger. The lettuce is harvested from the sixteen lettuce plants growing around the top of the solar pond.

Tests were carried out using both tilapia and yellow bullhead catfish in the hydroponic solar pond system. Catfish can tolerate much lower temperatures than tilapia, and, young catfish can be obtained more easily than young tilapia, especially in smaller household quantities.

Solar Pond Aquaculture – References

The Journal of the New Alchemists No. 2 1974 134 pp. editor Nancy Jack Todd (publ. New Alchemy Institute.)
[selected articles

- “Irrigation of Garden Vegetables with Fertile Fish Pond Water”. by Wm. McLarney
- “Walton Two: A Complete Guide to Backyard Fish Farming” by Wm. McLarney & John Todd. pp 79–11
[a working manual of tilapia aquaculture reviewing previous 3 year’s research.]

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- [selected articles] “The Trash Fish Cook Book” by Wm. McLarney & Bryce Butler
“Further Experiments in the Irrigation of Garden Vegetables with Fertile Fish Pond Water”
by Wm. McLarney

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- “Fertile Fish Pond Water Irrigation Trials” by Susan Ervin
- “The Saga of the Solar-Algae Ponds” by Ron Zweig
- “Three Experiments with Semi-Enclosed Fish Culture Systems” by Ron Zweig
- “Cage Culture” by Wm. McLarney

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- “On the Cryptic Phrase “Mathematical Modelling – John Wolfe
- “Open System Fish Culture – 1977 “ Wm.McLarney & Jeffrey Parkin
- “Investigations of Semi-closed Aquatic Ecosystems” by Ron Zweig
- “The Birth and Maturity of an Aquatic Ecosystem” by Ron Zweig
- “Where Does All the Heat Go?” by Joe Seale
[a computer model to calculate heat in the PEI Ark]

The Journal of the New Alchemists No. 6 1980 186 pp. editor Nancy Jack Todd (publ Stephen Green Press
ISBN-8289-0367-0)

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- “Cage Culture” Wm. McLarney & Jeffrey Parkin
- “Solar Aquaculture :
 - Historical Overview by Ron Zweig
 - The Dome as Nursery by Ron Zweig
 - Summary of Fish culture Techniques in Solar-Algae Ponds by John Wolfe & Ron Zweig
 - Sunlight Patterns Without, Chemistry Patterns Within : the View from a Solar Algae Pond
by John Wolfe, Dave Engstrom, Ron Zweig
 - The Energetics of Solar-Algae Pond Aquaculture by John Wolfe
- “From Our Experience : The First Three Years Aboard the Cape Cod Ark”
Part 6 – A Review of Aquaculture in the Ark by Ron Zweig

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8289-0406-0)

[selected articles

- “Alternatives to Commercial Feeds in the Diets of Cultured Fish” Wm. McLarney & Jeffrey Parkin
- “Defining & defying Limits to Solar-Algae Pond Fish Culture” by Dave Engstrom, John Wolfe, and Ron Zweig
- “Modelling Algal Growth and Decline in Solar-Algae Ponds” by Dave Engstrom, , and Ron Zweig

TECHNICAL BULLETIN # 2. How To Construct a Solar Algae Pond. by Carl Baum and Ron Zweig. 4 pp.

Solar Aquaculture : Perspectives in Renewable, Resource-Based Fish Production

A Report to the National Science Foundation (151 pp.) September 1981.

[this is a final report summarizing all research & computer modelling of solar pond aquaculture up to June, 1982]

by Ron Zweig (co-principal investigator) Robert Angevine (administrative officer)
John Todd (co-principal investigator) Albert Doolittle (computer monitoring specialist)
John Wolfe (ecosystem analyst) David Engstrom (water chemist)

Six progress reports were written as background to the above final report :

“Assessment of a Semi-Closed, Renewable Resource-Based Aquaculture System”

Progress Report No. 1 “A Six-Month Progress Report “ May 23, 1978 88 pp. by John Todd & Ron Zweig

Progress Report No. 2 [not found]

Progress Report No. 3 - May 20, 1979 . 134 pp. (experiments from April 1978 to April 1979)

+ 14 appendices re: solar pond aquaculture, including :

I Instrumenting the Arks. by Albert Doolittle & Charles Rockwell.

II. Looking for a New Aquaculture : The Roads Ahead. by John Todd

IX Agriculture & Aquaculture in Bioshelters : The New Alchemy Experience.
by John Todd & John Wolfe.

X The Energetics of Solar Pond Aquaculture. by John Wolfe

Progress Report No. 4 - December 7, 1979 (experiments from May 1979 to Sept 1979)

Progress Report No. 5 - September 22, 1980

Progress Report No. 6 - Part 1 Experimental Data - June 30-1982

Progress Report No. 6 - Part 2 Computer Simulation Model September 1981

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5. Summer 1981.. 16 pp.

— Aquaculture - Hydroponics in the Ark. by Peter Burgoon

14. Winter 1983: 24 pp.

— Seasonal Aquaculture : Outdoor Summer Production. by Ron Zweig & Linda Gussman

18. Winter 1984.. Do Integrated Systems Really Work Better? . 24 p

— When Do Solar Algae Ponds Make Cents?. by Ron Zweig.

19. Spring 1985: Growing Food in Water: The Art & Science of Aquaculture and Hydroponics. 24 pp.

— Why Aquaculture? by Wm. McLarney

BOOKS :

Backyard Fish Farm Book; Growing Fish in Floating Cages. ,1981. 77 pp. William McLarney and Jeffrey Parkin
Brickhouse Publishing co.

Gardening for All Seasons 1983. 309 pp. by staff of New Alchemy Institute.
editors Gary Hirshberg and Tracy Calvan. Brickhouse Publ.

REPORTS ABOUT THE ARK ON PRINCE EDWARD ISLAND, CANADA

(the Ark on PEI was built by New Alchemy PEI in 1976, and operated by NAI PEI until 1978.

The PEI Canadian provincial government then managed it until June 1981.)

An Ark for Prince Edward Island : A Report to the Federal Government of Canada. Dec 30, 1976. Book 11” h x 22”
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