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A unique approach to the problem of safely transporting juvenile fish by truck has been designed and tested.

Aircraft-Refueling Trailer Modified to Haul Salmon and Trout

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ABSTRACT

Two 5,000 gallon tanks from aircraft-refueling trailers were modified and equipped with life support systems to haul juvenile fish (seaward migrants) past various sections of the Snake and Columbia Rivers. The tanks and life support systems were evaluated from observations of fish mortality and water quality measurements recorded during hauls of a total of 1.4 million fish comprised of hatchery and wild stocks. Mortalities ranged from 0.05 to 1.33 percent. Analysis of water quality in the tanks indicated that the life support systems were suitable for hauling loads of up to 1.5 pounds of fish per gallon of water for 300-450 miles (5-10 hr duration).

INTRODUCTION

Anadromous salmon and trout that spawn in the Columbia and Snake Rivers (the Snake River is a large tributary of the Columbia) constitute a valuable marine resource off the west coast of the United States for both commercial and sport fishermen. In recent years, there have been substantial losses of the juvenile migrants directly attributed to problems associated with dams and reservoirs (Long and Krcma, 1969; Ebel, 1970) on the two rivers. As a result, the National Marine Fisheries Service has been conducting studies to determine whether a system of collection and transport of seaward migrants might be a possible solution for reducing the losses.

Implementation of such a system would require vehicles that can haul large numbers of live fish over long distances. Two surplus aircraft-refueling tanks with a capacity of 5,000 gallons were altered and fabricated with life support systems for use in these experiments.

This report describes the tank trucks (with the special emphasis on the life support systems used in the tanks) and presents a brief summary of the use of the trucks in 1972 to transport fish downstream.

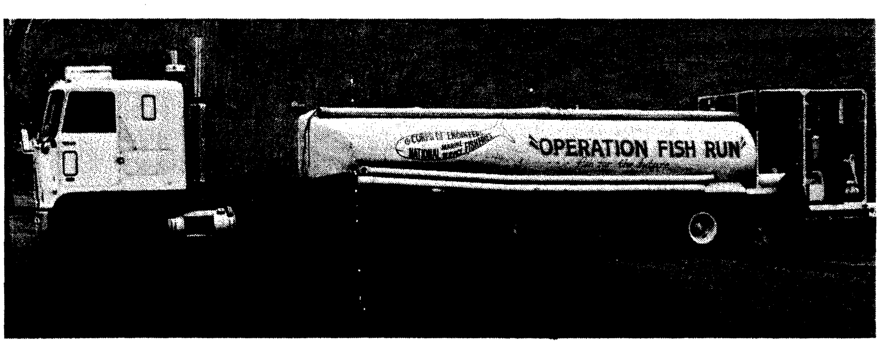

Figure 1. — Truck and trailer used by NMFS to haul juvenile salmon and trout down the Snake and Columbia Rivers in 1972.

FISH TANKS AND LIFE SUPPORT SYSTEMS

The tanks that we used for hauling fish originally had been used to haul aircraft fuel. Pumps, gauges, and other equipment used in refueling aircraft were removed. The interiors were sandblasted, steam cleaned, epoxy painted, and checked for toxicity before life support systems were installed. The exterior of each tank was insulated with 3 inches of styrofoam.

Each tank was divided into two main compartments, the forward compartment having three splash baffles and the rear compartment having a single baffle. The combined capacity of the compartments was 5,000 gallons. However, part of the interior was needed for the overhead sprinkler system which reduced the hauling space to about 4,000 gallons, with 2,200 gallons in the front compartment and 1,800 in the rear compartment. A refrigeration unit, recirculating pump, and filter, in addition to liquid and compressed oxygen bottles, were installed on a platform at the rear of the trailer. The complete unit was 35 feet long overall; the tank, 26 feet long (Figure 1).

A model R-1000D refrigeration system, made by Harris Thermal Transfer Products, Inc.,[1] was used for cooling and recirculating the water supply. The 120,000 BTU system can provide a maximum 10 degrees per hour pull-down and maintains a preset temperature within 1.8°F (± 1°C). This model chiller was specifically designed to avoid clogging.

The primary recirculating pump, which was provided with the chiller, was capable of circulating 150 gallons of water per minute. Spray aeration from overhead nozzles and from jets near the bottom of the tank provided oxygen and also insured adequate water exchange in all areas of the tank. (See Figure 2 for diagram of recirculation and aeration system.) A 3 × 16 inch cylindrical standpipe covered with mesh screen was placed over each of the six intakes (to the refrigeration unit) which were evenly spaced in the bottom of the tank. These standpipes prevent dead fish from blocking the intake lines. Each of six intake ports was fitted with an orifice to provide even distribution of flow from all intake ports regardless of location from the main intake line. A standby pump with 150-gpm capacity was also provided for recirculation and aeration of water in case of failure of the refrigeration unit. The entire water supply could be circulated through the chiller and auxiliary pump in about 27 minutes.

A Model PF-100 sand filter, manufactured by the Pacific Manufacturing Company, was incorporated into the recirculating system to reduce the amount of foam, slime, feces, scales, and regurgitated food in the tank. The device could be adjusted to control the amount of water passing through it; the volume of flow was determined by means of a flowmeter on the output side of the filter. Maximum filtering capacity of the system was 100 gallons per minute, and its working pressure was 50 pounds. The filter could be cleaned by flushing about 70 gallons of water back through the output side of the device.

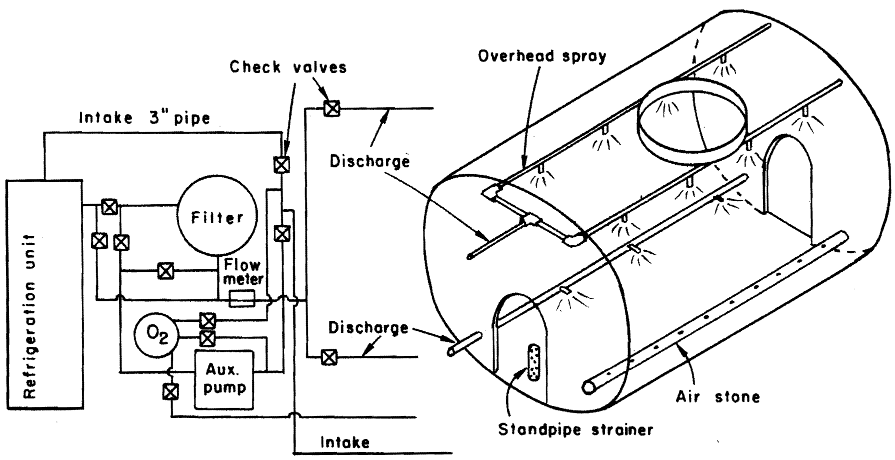

Figure 2. — Diagrammatic view showing life support system in one of the six sections of the tank truck.

Oxygen was discharged into the tank through six carborundum stones (2 inches in diameter and from 24 to 54 inches long depending on location in tank) or through the recirculating pump intake or both. One liquid oxygen bottle (LC-3 size) served as the main supply. The bottle was equipped with an expansion chamber which allowed a continuous supply of gas at a pressure of 40 psi. Oxygen flow was controlled by a medical type flowmeter which was accurate to within ±0.13 gallon (±0.5 liter) gas per minute. One cylinder of oxygen of 3,000 pound-pressure was also carried for emergencies.

Temperature, oxygen input, recirculating pump pressure, and oil pressure of the refrigeration unit were monitored from the cab of the truck.

FISH HAULING OPERATIONS IN 1972

About 1.4 million juvenile salmon and steelhead trout, *Salmo gairdneri*, were hauled. The majority were smolts — some were taken directly from hatcheries and others were captured during their seaward migration.

Fish Hauled from Hatcheries

About 820,000 of the fish hauled were taken from hatcheries. Approximately 320,000 of the hatchery fish were transported a rather short distance — 30 miles — to test the truck systems, but the remaining 500,000 were transported a considerable distance — 450 miles — down the Columbia and Snake Rivers.

Coho salmon, *Oncorhynchus kisutch*, that were hauled 30 miles for test purposes were transported from Ringold Hatchery to holding pens near Pasco, Wash., 8-10 February 1972. Load densities varied from 0.5 to 1.5 lb of fish per gallon of water (Table 1). Mortality was nil and oxygen concentrations remained high. Obviously, the transport system was never loaded to capacity. During one trip we wished to examine the efficiency of the aeration stones for oxygenating the water. All other life support systems were inactivated. This transport was made with a light load of 0.5 lb of fish per gallon of water. Dissolved oxygen at destination after a 60-minute haul was reduced to a

[1] Reference to trade names in this publication does not imply endorsement of commercial products by the National Marine Fisheries Service.

Table 1.—Transport data from loads of various densities of fingerling coho salmon (20/lb) hauled from Ringold Hatchery to Pasco, Wash., February 1972.

Load density (lbs/gal)	Temperature (°F) Start of loading	Destination	Concentration of oxygen in tank (PPM) Start of loading	Start of transport	Destination	Haul time (min)	Recirculating system operating	Oxygen fed, metered, to tank (LPM) To stones	To recirculating pump intake	Mortality (%)
0.5	45	46	11.1	—	6.4	60	No[1]	7.0	No	0
0.75	39	39	11.9	—	—	60	Yes	3.0	3.0	0
0.83	41	42	14.7	7.9	—	90	Yes	3.5	1.5	0
0.87	48	46	13.4	13.4	12.1	100	Yes	3.0	3.5	0
0.90	44	45	16.8	11.4	10.8	90	Yes	3.5	1.5	0
1.0	48	48	13.3	9.6	10.0	60	Yes	3.0	3.5	0
1.1	41	43	12.6	10.0	7.4	120	Yes	3.0	1.5	0
1.5	39	39	14.5	15.3	—	60	Yes	5.0	3.25	0

[1] Recirculating system operational during loading.

minimum tolerable level of 6.4 ppm. Evidence accumulated from these series of hauls indicated that injecting oxygen into the intake line of the pump was more efficient than injecting through stones to maintain an acceptable oxygen concentration.

The hauls of 450 miles were made in April from Rapid River Hatchery, Idaho, to Bonneville Dam, which took from 10 to 12 hours. Spring chinook salmon, *O. tshawytscha*, in smolting condition were hauled in these tests. Basic water quality data such as temperature and oxygen concentrations were recorded at the destination of each load along with mortalities that occurred during the hauling period.

Mortality of hatchery fish transported 30 and 450 miles was always under 0.05 percent. Thus from these data, we considered the tank more than adequate for hauling hatchery smolts (the above fish were hauled at densities of 1 lb of salmon per gallon of water over the longer distance and up to 1.5 lb per gallon for the shorter distance). The tanks were never loaded to capacity when all life support systems were operational; further testing is needed to determine the maximum carrying capacities for hatchery stocks.

Transport of Fish Captured During Migration

In the spring, a total of about 600,000 chinook salmon and steelhead trout were collected at Little Goose Dam and transported to Bonneville Dam, a distance of about 350 road miles. Water in the tanks was analyzed at Bonneville Dam for concentrations of ammonia, nitrogen, dissolved oxygen, carbon dioxide, pH, and total alkalinity. Basic data recorded during the hauls when hatchery-reared fish were transported were also recorded when smolts captured during migration were transported. These data provided a basis for judging water quality control in our system.

Table 2.—Transport data from six loads of chinook salmon and steelhead trout (mixed) hauled from Little Goose Dam to Bonneville Dam, 1972.

Date	No. fish in load	Pounds per gal.	Mortality Number	Percent	Water quality from transport tank at dest. O_2	CO_2	NH_3	pH	Total alk.
5-6	33,000	0.84	350	1.06	9.8	17.0	4.0	7.2	84
5-8	43,076	1.10	243	0.56	9.8	25.0	7.0	6.8	74
5-9	43,313	0.95	400	0.92	10.38	26.0	7.0	6.8	72
5-10	40,440	1.10	1,300	3.21	11.96	29.0	8.0	6.8	73
5-11	44,118	[1]1.10	696	1.56	18.15	15.0	6.2	6.8	62
5-12	39,146	[2]1.05	275	0.70	16.05	14.5	3.0	6.8	60

[1] 1.5 pounds per gallon in rear compartment (1.1 overall load density).
[2] 1.2 pounds per gallon in front compartment (1.05 overall load density).

Of the above fish, 260,000 were used in a study to obtain information on water quality and mortality of fish associated with "high density" loads (Table 2). The water quality data from the above loads indicate that oxygen was more than adequate. The pH values were at a level where interaction between pH and toxicity of ammonia did not become a critical factor influencing mortality. The average mortality of the transported fish was 1.33 percent. In addition to these high density loads, 350,000 other smolts were hauled in 33 trips to the Bonneville release site. Average mortality in these loads was 0.55 percent. All loads from Little Goose Dam were hauled in turbid, Snake River water, which made filtration necessary.

Although higher mortalities occurred with the captured migrating fish than with the fish taken directly from hatcheries, we believe that the tank and life support systems are nearly optimal for the former group of smolts. The higher mortality of captured migrating fish did not appear to be related to a subtle stress factor associated with the response of this group of fish to hauling. Rather, it appeared to be directly associated with injuries incurred at the time of capture at Little Goose Dam (examination of dead smolts at the release site revealed that 90 percent had some descaling or other injury that probably occurred prior to hauling).

Table 3. — Number of fish and quantity of water needed at start of haul for load density of 0.25 lb of fish per gallon of water[1] (number of fish and quantity of water, of course, will vary with average body size of fish).

Size of fish (fish/lb)	Quantity of water in tank (gallons)										
	1,000	1,100	1,200	1,300	1,400	1,500	2,000	2,500	3,000	3,500	4,000
1	250	275	300	325	350	375	500	625	750	875	1,000
2	500	550	600	650	700	750	1,000	1,250	1,500	1,750	2,000
3	750	825	900	975	1,050	1,125	1,500	1,875	2,250	2,625	3,000
4	1,000	1,100	1,200	1,300	1,400	1,500	2,000	2,500	3,000	3,500	4,000
5	1,250	1,375	1,500	1,625	1,750	1,875	2,500	3,125	3,750	4,375	5,000
6	1,500	1,650	1,800	1,950	2,100	2,250	3,000	3,750	4,500	5,250	6,000
7	1,750	1,925	2,100	2,275	2,450	2,625	3,500	4,375	5,250	6,125	7,000
8	2,000	2,200	2,400	2,600	2,800	3,000	4,000	5,000	6,000	7,000	8,000
9	2,250	2,475	2,700	2,925	3,150	3,375	4,500	5,625	6,750	7,875	9,000
10	2,500	2,750	3,000	3,250	3,500	3,750	5,000	6,250	7,500	8,750	10,000
11	2,750	3,025	3,300	3,575	3,850	4,125	5,500	6,875	8,250	9,625	11,000
12	3,000	3,300	3,600	3,900	4,200	4,500	6,000	7,500	9,000	10,500	12,000
13	3,250	3,575	3,900	4,225	4,550	4,875	6,500	8,125	9,750	11,375	13,000
14	3,500	3,850	4,200	4,550	4,900	5,250	7,000	8,750	10,500	12,250	14,000
15	3,750	4,125	4,500	4,875	5,250	5,625	7,500	9,375	11,250	13,125	15,000
16	4,000	4,400	4,800	5,200	5,600	6,000	8,000	10,000	12,000	14,000	16,000
17	4,250	4,675	5,100	5,525	5,950	6,375	8,500	10,625	12,750	14,875	17,000
18	4,500	4,950	5,400	5,850	6,300	6,750	9,000	11,250	13,500	15,730	18,000
19	4,750	5,225	5,700	6,175	6,650	7,125	9,500	11,875	14,250	16,625	19,000
20	5,000	5,500	6,000	6,500	7,000	7,500	10,000	12,500	15,000	17,500	20,000

[1] The number of fish needed for other load densities can be easily obtained by applying this table. For example, a load density of 0.50 lb of fish per gallon of water would require twice as many fish as shown above; a load density of 1.00 lb would require four times as many fish.

The tank safely held chinook salmon and steelhead trout in densities up to 1.5 lb of fish per gallon of water. Based upon our observations, we believe 1.5 lb per gallon may be near capacity for the unit when hauling smolts that had been captured during their seaward migration.

To simplify loading operations at Little Goose Dam, we developed a table that was used to determine the number of fish to be loaded to attain any desired density (Table 3). Although the table was of particular value to us, it could also be applied to any hatchery release operation where tanks of 1,000-4,000 gallon capacity are used.

ACKNOWLEDGMENTS

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