to cover a great deal of material. We will, therefore, turn the meeting over to you, Admiral Rickover, and you may proceed when ready.

STATEMENT OF ADM. H. G. RICKOVER, CHIEF, NAVAL REACTORS BRANCH, ATOMIC ENERGY COMMISSION

Admiral RICKOVER. Thank you, sir. This is the first time I have been at the committee since Carl Hinshaw died, and as a witness who has appeared here many times and who has been questioned by him very pointedly, I would like to express my sincere regrets that he is not with us here today so he could continue to ask so many pointed questions, as he always did.

Although I used to accuse him of being for the Air Force, he was really for everybody, and helped us in the Navy a great deal.

Representative PRICE. We certainly miss him on the committee in many ways.

Admiral RICKOVER. There are a number of activities in the naval program that have no names. I wonder if it would be desirable to name one of these activities after Carl Hinshaw?

Representative PRICE. I think it would be very desirable, and I hope you can find a suitable one to dedicate to his memory.

Admiral RICKOVER. We can find one. I talked to the chairman of the board of Combustion Engineering. They have their new plant at Windsor, Conn., and I think they would be very happy to name it the Carl Hinshaw Laboratory. There are other places too.

If the committee cared that this be pursued, I would be happy to do so.

Representative PRICE. I think the committee would be very happy to have you do it. I think also the first flying prototype of a nuclear aircraft would be a fitting memorial to Mr. Hinshaw.

Admiral RICKOVER. But an aircraft carrier might come first.

Representative PRICE. You may proceed, Admiral, with your presentation.

Admiral RICKOVER. It has been frequently said that the things that have been done in the naval program have been done by a combined industry, AEC, and Navy team. I consider the Joint Congressional Committee to be an additional member of that team. I know and you people know that you have been just as much behind our program as anyone else and I very sincerely feel that way, because I know that without all your help and your confidence during the time when there was not anything to show you, without your backing we would not have progressed as far as we have.

The models I have in this room today are some examples of that, because all of them have either been built or are under construction

I will touch briefly on the naval program and then tell you about some of the advanced things we are doing, as you requested, sir.

The *Nautilus* was refueled about a week ago. She will again be ready for operation in about a month. Her first core ran for 62,500 miles, of which about 37,000 miles were fully submerged. The core lasted longer than we expected.

The new core will last even longer. This additional core life is being obtained without any increase in cost of manufacture, so that in effect when we increase the life of the core we cheapen it; even though it may cost the same it cheapens it in that proportion.

Representative PRICE. Would you mind comparing that performance with the performance of a conventional submarine.

Admiral RICKOVER. Yes, sir. During this process of steaming 62,500 miles, a conventional submarine having equal horsepower would have burned about 2,170,000 gallons of oil, the amount contained in 217 tank cars, with a length 1.7 miles long.

Representative VAN ZANDT. How long?

Admiral RICKOVER. 1.7 miles long; 2,170,000 gallons. That is the equivalent amount of fuel oil a conventional submarine of that power and having the same displacement as the *Nautilus* would have burned. The new core should do better than that.

Representative COLE. What is the price of that?

Admiral RICKOVER. Diesel oil, I think, costs about 8 to 10 cents a gallon, something on the order of 9 cents. I am not absolutely certain of the cost.

Representative VAN ZANDT. Are you good at arithmetic?

Admiral RICKOVER. That would be about $200,000 worth of oil. It is not much in cost. I do not want to leave any impression with this committee that to run a nuclear-powered vessel is cheaper than a conventional one. It is not. Because the amount you save by the oil is insignificant compared to the cost of the reactor core on present prices.

However, the cost of cores is coming down.

I do not want to create any wrong impression on that score.

As I stated, the new core will have more life. We already have evidence of that. As I stated, the *Nautilus* will be ready for sea in April and her core should be good for more than 2 years without refueling.

Representative VAN ZANDT. What did you find on the inside of the reactor, as far as the metals that were employed? I am thinking now of the pipes and so forth.

Admiral RICKOVER. We looked inside the pressure vessel of the *Nautilus* after the core was removed and it was shiny and clean. We found nothing wrong. During the refueling operation no one was irradiated beyond 300 milliroentgens a week, which is the normal permissible by AEC standards—no more irradiation than is allowed in an AEC laboratory for a week. I think 250 milliroentgens was actually the maximum dose.

Representative VAN ZANDT. In the beginning you recall in the design of the *Nautilus* there was piping used that could not take the pressure. I am wondering what did you find in conection with that redesigning?

Admiral RICKOVER. There was no faulty pipe found. A mistake had been made during the building period in 1954. Some wrong pipe had been used in the steam system instead of the pipe which had been specified, but this was corrected before the ship ever went to sea.

At Arco—perhaps I had better talk for a few moments on what we are doing there. We are using that installation as a training facility and as a test facility for trying out new reactor ideas.

For instance, it was there we tried out fuel elements that gave us increased life.

We have trained about 60 officers and about 500 enlisted men on the submarine prototype at Arco. Just before I came up here today,

I heard that we are losing 6 percent per year of all the enlisted men in the nuclear program because they become officers; 20 times as many enlisted men in our program become officers as do in the rest of the Navy.

I am not happy about this loss, but it is good for morale, and it is good for the Navy.

Of course, not all of the credit belongs to our training program. Our selection procedure obtains a high class of people for the program. That helps account for it. It does pose a serious problem to lose so many men, but it results in overall good to the Navy.

Representative VAN ZANDT. What about the initial selection? Have you an unlimited reservoir to select from as far as enlisted personnel is concerned?

Admiral RICKOVER. Enlisted personnel for the program are selected by the forces afloat, but we have fairly strict requirements, such as 4 years obligated service, and graduation from high school. Also a good record and above-average ability and intelligence.

We have, first, a 6 months' course at the submarine school in New London. This is a special course where we teach physics and mathematics, and various nuclear courses. After the course at New London the men are sent to Arco for another half year. There they learn how to operate and service the plant. They are then assigned to nuclear-powered ships.

The officers for the nuclear propulsion program are designated by the Bureau of Naval Personnel. They are also given 6 months' theoretical training and 6 months at Arco. Their course is much more difficult than that the enlisted men. All of the officers and a number of the enlisted men qualify as chief operators before they complete the course. This is a very difficult thing to do, but it assures us of having competent people for our nuclear plants. Admiral Holloway, our Chief of Naval Personnel, has been very farsighted in understanding our problems, and has gone out of his way time and again to help us. Without his help we could not have accomplished what we have.

Representative COLE. How does the enlisted man get to be an officer?

Admiral RICKOVER. The Navy conducts examinations twice a year.

Representative COLE. What additional training does he have in order to become an officer, none?

Admiral RICKOVER. No, sir. When he is selected for officer he is then sent to an officer candidate's school. There he is given special training for about 6 months and, if he completes the course, he is commissioned.

Representative COLE. Is he a general officer, a line officer?

Admiral RICKOVER. Yes, he becomes a line officer, an ensign.

The year's training we give the sailors and officers in our program is very valuable. I have been told that to qualify as Chief Operator at our prototype at Arco is several times as difficult as it is to qualify for command of a submarine.

It requires about 1,000 hours of practical work for this qualification, and this is in addition to all of the study they do. They must become adept in all phases of reactor operation, particularly in everything that pertains to safety. Even the commanding officers work 16 hours a day, 7 days a week at Arco.

I will say no more on training, except I must add that the facility at Arco is most valuable from this standpoint. We have no better training facility in the Navy than we have there and it is absolutely essential for the future of nuclear power in the Navy that we train the people there, on a real plant, a live one, because we do not want any accidents to happen. We want them to know the plant inside out. I am proud of the fact that all of the officers and men in the program are outstanding. They are all a marvelous group of very fine people and I am sure that ultimately they will be the leaders in the Navy.

Senator HICKENLOOPER. May I ask a question of Admiral Rickover?

Do you have a rough approximation of the cost of the operation of the *Nautilus* so far as fuel is concerned? Take the 2,170,000 gallons of fuel oil. That cost compared with the cost of nuclear heat, the core, its replacements, and utility of the core.

Leave out the plant itself.

Admiral RICKOVER. It is rather meaningless to say we are saving money. What we are getting is a profound military advantage.

Senator HICKENLOOPER. I understand that, but I just wanted to get some approximation.

Admiral RICKOVER. This gets into the problem of the cost of atomic power. At the present time, and for the next 10 years, I do not believe atomic power can compete economically with conventional power. We are still in the development stage. We are still learning how to develop and manufacture nuclear cores.

At Shippingport the cost of the power will be between 55 to 65 mills per kilowatt.

I believe it is rather farfetched to expect nuclear power to be competitive with conventional power for the next few years. I do not say it will not happen, but not today, not for the next few years.

Representative VAN ZANDT. What was the cost of the *Nautilus* per kilowatt?

Admiral RICKOVER. In wartime the cost was about 8 cents per kilowatt-hour on a conventional submarine.

Representative VAN ZANDT. You said 8 cents?

Admiral RICKOVER. That is 80 mills. But if you took into account the cost of convoys and fueling stations and other factors, I am not so sure that from an overall standpoint you would find, taking all the other factors into account, that nuclear power on a warship is more expensive than conventional fuel. I am not talking now about the military advantages we get from the use of nuclear power. Nuclear power gives us ships that can go at high speeds and can stay submerged for days at a time.

One of the things we did with the second core at Arco was to run it for 66 days and nights continuously at full power. The lines on this map [indicating] show the distance a nuclear submarine would have steamed under the same circumstances, on a full-power nonstop run. It would have run once around the world and back to New London, and without stopping set out again and go around the world on a northern route. That is a longer continuous run at full power than a plant of any kind, land, sea or air, has ever made. In contrast, the Navy acceptance trial at full power for a new ship is 4 hours. This plant ran for 1,700 hours continuously at full power.

Representative PRICE. Which reactor is that?

Admiral RICKOVER. It is the one at Arco, and is similar to the one that has just been installed in the *Nautilus*.

Representative PRICE. Similar to the *Nautilus?*

Admiral RICKOVER. Similar to the one that has just been placed in the *Nautilus*.

Representative PRICE. The new *Nautilus* reactor?

Admiral RICKOVER. Yes, sir.

Representative VAN ZANDT. The *Nautilus* is equipped with auxiliaries?

Admiral RICKOVER. Yes, sir.

Representative VAN ZANDT. Both diesel as well as batteries?

Admiral RICKOVER. There are two 300-horsepower diesels used for supplying auxiliary power in port. They are capable of propelling the *Nautilus* on the surface at slow speed if the ship had to do so in an emergency.

Representative VAN ZANDT. At any time during her life so far have you had to fall back on your auxiliaries?

Admiral RICKOVER. Yes, sir; we have fallen back on storage batteries for a short time, but Admiral Watkins, who is commander of the Submarine Atlantic Fleet, has told me that the *Nautilus* has operated with as great a reliability as any submarine he has in his entire force. She has not once failed to meet a planned operating commitment.

I understand you are going to have Captain Wilkinson in here next week to testify.

Senator JACKSON. Monday.

Admiral RICKOVER. He will come before Senator Jackson's committee, and I hope you ask him some of these questions.

The *Nautilus*, of course, has operated much more than any conventional submarine since she has been in commission.

Senator JACKSON. In order to get a proper projection of costs on the operation of the *Nautilus*, you would have to project the *Nautilus* into, say, 50 such ships.

Admiral RICKOVER. Yes, sir.

Senator JACKSON. And compare it with 50 conventional submarines with all the supporting elements, would you not, in order to get a fair overall operating cost?

Admiral RICKOVER. Yes, but Senator, you have a lot of intangibles in there, too. A war machine cannot be judged by cost.

Senator JACKSON. No.

Admiral RICKOVER. Cost is one factor. But a more important factor is, What can she do?

Senator JACKSON. In other words, the contribution she can make to our national security.

Admiral RICKOVER. I do not know how you are going to equate the operating cost with the military value.

Senator HICKENLOOPER. My question did not go to holding you down to dollars-and-cents cost. I want to get an approximation of comparison.

Admiral RICKOVER. Would you want me to get this information and file it for the record? I will be glad to.

Senator HICKENLOOPER. If it is at all reliable. I realize there are many, many intangibles involved.

Admiral RICKOVER. Yes, sir.

Senator HICKENLOOPER. You also have an experimental ship and have done a lot of experimenting with this thing, and I presume it would be very difficult indeed to get down to any accurate cost accounting on this thing. I just wanted to get some idea.

Admiral RICKOVER. I think I have given you a rough idea.

Senator HICKENLOOPER. Yes.

Admiral RICKOVER. I think the best way to sum it up is to state that the *Nautilus* is not a new type submarine; she is really a new weapon. I think you just cannot compare it with any conventional submarine. You would be comparing two dissimilar things. It is very difficult for most people, including people in the Navy, to realize, that a nuclear submarine is really a new weapon. We are going to be faced with the same problem in the Navy when we get the first nuclear-powered surface ship.

The next class of submarine after the *Nautilus* was the 578 class. This model [indicating] shows the *Nautilus*. It is 320 feet long and makes over 20 knots. It displaces 3,200 tons on the surface.

There are five of the 578 class. Four will be attack submarines and the fifth one will be a guided-missile submarine which is now being built at the Mare Island Naval Shipyard. Keels of all five have been laid. The first one, the *Skate*, will be launched in May at Electric Boat, and should be at sea about the end of this year or early next year.

This one [indicating] the *Skipjack*, is the latest type, with an *Albacore*-type hull. It has a single propeller.

The reason we went to a faster submarine was because soon after the *Nautilus* went out on her trials it became evident that for a submarine to remain effective against the most modern type of antisubmarine methods, she would have to make higher speeds.

Therefore, we designed this ship and she should be in operation about June of 1958.

Incidentally, the *Sea Wolf* went to sea this morning at 8 o'clock. Perhaps you would want to hear about the *Sea Wolf?*

Representative PRICE. Yes.

Admiral RICKOVER. I will get on that story now. I hope you do not mind me jumping around on this testimony.

Representative DURHAM. I would like to hear about the *Sea Wolf*.

Admiral RICKOVER. As you know, the *Sea Wolf* reactor uses sodium as a coolant instead of the ordinary water used in the *Nautilus* reactor. Sodium becomes about 30,000 times as radioactive as water. Furthermore, sodium has a half-life of 14.7 hours, while water has a half-life of about 8 seconds. As we went on with the testing of the *Sea Wolf* we found that even a very small leak in the heat exchangers would cause serious trouble. We went to full power on the *Sea Wolf* alongside the dock on August 20 of last year. Shortly thereafter she developed a small leak. It took us 3 months, working 24 hours a day, to locate and correct the leak. This is one of the serious difficulties in sodium plants. When you do have trouble, a considerable amount of time and expense is involved in correcting it because of the high radioactivity. We found that the trouble was a type of corrosion of stainless steel called stress corrosion; stainless steel has a tendency to become corroded by sodium. This means that unless the heat exchangers are absolutely tight and never leak there will be trouble.

We managed finally to fix the heat exchangers on the *Sea Wolf*.

We cut out some of the heat exchanger capacity which reduced the power about 10 percent. We also cut the superheaters out of the system which reduced the power another 10 percent. The *Sea Wolf* went to sea on the 21st of January, and she has been operating since that time. With the reduced power she makes about 90-percent speed.

I was on her during her first sea trials. She steamed about 800 miles, half of which were submerged. After operating for 4 or 5 days she went into drydock for structural repairs. This had nothing to do with the atomic powerplant. She got out of drydock and was at sea again for 8 to 10 days.

If a leak develops in a sodium plant on board ship—I am not talking about shore sodium-cooled plants—then it is quite serious to repair. The radioactivity must be left to decay, and repairs are lengthy and expensive.

But if you had a thimbleful of leakage in a sodium plant you probably could not run.

Senator BRICKER. What is the reason for adopting the sodium coolant?

Admiral RICKOVER. At the time we started on the nuclear propulsion program, sir, we went to two equivalent approaches. At that time, in 1947, we did not know which one would work. As a matter of fact, at that time we thought sodium had a better chance of working than water. Sodium had been chosen by General Electric for their power breeder at the Knolls Atomic Power Laboratory. Later on, when the Commission found that the design of the sodium-cooled power breeder was not going along well and the expense to build it would be too great, it was changed to a naval submarine project and we in the Naval Reactors Branch took it over.

No one knew at that time which would work better, and since atomic power was extremely important for the Navy we decided to follow the two approaches, but we did not know then which would be better. In fact, we were not then definitely sure that either one would work. Now that we have had the chance to operate both the *Nautilus* with her water-cooled plant, and the *Sea Wolf* with her sodium-cooled plant, it is obvious that water is much better than sodium for naval plants. All other nuclear ships, submarines and surface vessels, are being designed for water-cooled plants.

Senator BRICKER. What did you say the half life of sodium is?

Admiral RICKOVER. 14.7 hours.

Representative VAN ZANDT. What percentage of pressure have you lost?

Admiral RICKOVER. We have not lost pressure. We have lost heat transfer capacity. We have lost about 20 percent. The bypassing of the superheaters and the plugging of some of the heat exchanger circuits have reduced the heat transfer by about 20 percent.

Representative VAN ZANDT. Then you are working with 80 percent of capacity today.

Admiral RICKOVER. Yes, sir. But if we get more leaks we will have to plug additional circuits, and reduce the capacity some more.

Representative VAN ZANDT. What has that done to the speed?

Admiral RICKOVER. It has cut the speed 2 to 3 knots so far. Of course, the speed of a ship is not cut in proportion to the loss in power.

Senator Bricker, I think you have to recognize that if you want to get ahead with any game of this kind you have to take a chance. You do not know if it will work and if something is important you have to go ahead on more than one. You went ahead fully, experimentally, on both sides.

Admiral RICKOVER. Yes, sir. I did not consider the *Nautilus* a success until it was demonstrated that it worked all right for a long period of time.

Senator BRICKER. Is there any advantage in the sodium coolant at the present time that you know of?

Admiral RICKOVER. Theoretically sodium has advantages which may pay off in shore plants. You can get much higher temperatures and steam pressures, which means greater efficiency. Also it is possible to use lower pressures to circulate the sodium in the primary system. This means less pumping power.

For example, in the *Nautilus* we use high pressure in the primary system in order to keep the water as a liquid instead of boiling over into steam. On the *Sea Wolf* we use low pressure, just enough to force the sodium through the system. For this reason the pumping power in the *Sea Wolf* is only one-fourth that in the *Nautilus*.

Sodium has the advantage that it does not rust away the surface of material as water does. For this reason small particles of radioactive material do not get into the system and remain there for longer periods of time, and make access and maintenance difficult.

There may be advantages for sodium for shore-based atomic power-plants but I cannot see it for a ship. It is too dangerous for a ship.

After the *Sea Wolf* returned from her first trials she was docked at the Electric Boat Co. We then moored a conventional submarine alongside her and flooded the latter's ballast tanks to see how much of the *Sea Wolf's* radiation would carry through the flooded ballast tanks and into the ship. Even with the ballast tanks full, enough irradiation came through to the conventional submarine to give her crew in that vicinity as much radiation in 4 hours as is normally permitted for a week. Of course, in a while the radiation would be reduced a great deal because it has a half-life of 14.7 hours.

These are some practical problems we have learned about sodium plants. I am not saying these all apply to shore-based sodium plants. I am confining myself to ships. It certainly does apply to ships. As a result of this situation on the *Sea Wolf* and because the Navy is not building any more sodium-cooled ships, the Commission has decided to shut down the Mark A prototype plant at West Milton, N. Y. In order to save money, we are shutting it down. There is a letter in process which states this, but which may not yet have reached the committee.

Representative DURHAM. The letter has been received today.

Admiral RICKOVER. I wanted to mention it.

Senator BRICKER. That will be the only sodium reactor, then, in the whole fleet of submarines.

Admiral RICKOVER. Yes, sir. We intend to keep on operating the *Sea Wolf* as long as we can. If we get another sodium leak we will analyze it and see how expensive it is going to be to repair it. If it is not too expensive we will repair it and keep on operating because we can get very valuable tactical information today from any nuclear-

powered ship. We are not planning to have any more sodium-cooled ships in the Navy at the present time.

Representative VAN ZANDT. Have you had any personnel problems as far as exposures?

Admiral RICKOVER. No, sir. The maximum exposure we have had in the *Nautilus* per year in 2 years of operation is about 2 roentgens. That is the total for the year. The average radiation of people in the *Nautilus* during the 2 years of operation has been about 200 milliroentgens a week, or two-thirds of what is permissible in AEC laboratories.

Representative DURHAM. That West Milton plant could be used for civilian power; could it not?

Admiral RICKOVER. Actually, since it first started up we have gotten out of that plant about 2¼ million kilowatts of electric energy, of which about three-fourths of a million was sent out over the Niagara-Mohawk system. The rest was used on the site. But there is not much income from the sale of this power, sir. The cost of operating the plant is pretty high. That is, you get a few thousand dollars for the power but it costs very much more to operate. That is not a good financial deal for the Government.

Representative PRICE. It is not a good prototype for a civilian reactor.

Admiral RICKOVER. No, sir; because a civilian reactor would use an entirely different type of heat exchangers and an entirely different reactor system. A civilian plant would also be much larger. We are expecting to use the sphere in which the *Sea Wolf* prototype is contained for a destroyer prototype. I will discuss this in a little while.

Senator JACKSON. While on reactors, what about the gas-cooled reactor; what is the situation there?

Admiral RICKOVER. For a naval vessel?

Senator JACKSON. For propulsion.

Admiral RICKOVER. We made studies of gas-cooled reactors in the early days before we decided on sodium or water or gas, and we came to the conclusion first that a gas plant would be heavier and take up more space, and second, there was no assurance that there would not be leakage of radioactive gas into the ship. You may be able to tolerate such leakage in a shore plant. Since we do not know yet how to make any gas system tight, I do not consider it practicable for a ship. You are always taking the chance that radioactive particles may carry over from the reactor into the propulsion system or that radioactive gas leaks into the atmosphere. You can irradiate the crew this way.

A plant using air as the coolant would be so large it is impracticable for a warship where space is limited. Therefore, you have to go to a closed cycle plant. This type of plant should be tried out ashore and on other types of ships before it is tried in a naval vessel.

The Maritime Commission and the Reactor Development Division are having studies made at the present time of gas-cooled reactors for marine application. My personal opinion is that it will take a number of years before there is a sufficient degree of reliability to permit us to go ahead with a closed cycle gas-cooled plant in a naval vessel.

You see, our program consists not alone of reactors but also of ships that are appropriated for by Congress and we have to meet a date, and

ships have to work. That is a difficulty I labor under. That is demonstrated by all of these models. Everything you see here either has been built or is being built. They are not pictures of reactors. They are items that have been or are being designed.

Representative PRICE. Admiral, it would be advisable if you would just specifically describe to us the different types of reactor programs you are engaged in at the present time and then we might direct our questions toward those various types of reactors that you are actually working on.

Admiral RICKOVER. Yes, sir.

Representative PRICE. And then discuss those you think might be valuable to put into future programs.

Admiral RICKOVER. I discussed the Nautilus and the Seawolf. I would like to go on because I have so much more to say. I have talked about the 578 class. There are four 578-class attack submarines and one guided missile submarine.

These are the 585 class [indicating], which are single screw. There is 1 in the 1956 shipbuilding program and 6 in the 1957 shipbuilding program.

Incidentally, it may interest you to know this: I just checked up the amount of kilowatts we are going to have in nuclear-powered ships in the Navy. Projecting the present rate of nuclear shipbuilding we would have by 1963 about 1½ million kilowatts of power in operation and an additional million kilowatts in ships under construction. So we might have either in operation or under construction by 1963 about 2½ million kilowatts of atomic power in the Navy.

Senator JACKSON. 600,000 more than Grand Coulee.

Admiral RICKOVER. Yes, sir.

Representative VAN ZANDT. What is the mission of the Albacore type?

Admiral RICKOVER. It is an attack submarine. It can carry standard torpedoes. But its nuclear plant can also be used for guided-missile submarines; there will be three in the 1958 program. There are also two other types of nuclear submarines.

One type, and the one I consider very important, is the radar picket submarine. The reactor plant is being designed by the Knolls Atomic Power Laboratory of the General Electric Co. It will have two reactors. The submarine will displace about 5,800 tons on the surface and 8,000 tons submerged. It will be by far the largest submarine ever built.

Representative DURHAM. Is there any difficulty in procuring the raw material?

Admiral RICKOVER. Yes, sir. You mean fissionable material?

Representative DURHAM. Not only that—zirconium.

Admiral RICKOVER. I am glad you mentioned that. I might as well say right now and get into that—in order to carry this naval program through we have had to build up an industry. The first type of industry we have had to build up is zirconium. We started several years ago when the Atomic Energy Commission made a contract under competitive bidding and selected the one which offered the best terms, Carborundum Co. They contracted to supply 325,000 pounds of sponge zirconium a year for 5 years at a cost of about $12½ a pound.

Last year in looking into our prospective program we decided that by late 1958 we would have to have enough additional zirconium

sponge-making facilities for 2 million pounds of sponge a year. An arrangement was worked out between the Navy Department and the Atomic Energy Commission whereby the Atomic Energy Commission made the contracts, the Navy supplied the money, and we brought three new organizations into the program. They were selected on the basis of competitive bidding to see which ones offered contracts which were to the best financial interests of the Government. One of those brought in was the National Distillers Corp. They are putting up their own plant and developing their own process to make a million pounds of zirconium sponge a year for us.

The National Research Corp., is another contractor with whom we made a 5-year contract. I think they are building facilities to make a minimum of 700,000 pounds a year for us by still another process.

We made another contract with the Carborundum Co. to supply us from another plant which would produce for us about 600,000 pounds a year for 5 years. In addition to these contracts we made one contract with the Wah Chang Corp. to operate the Government-owned pilot plant we had at the Bureau of Mines in Albany, Oreg. Still another source of supply is the Hugo Neu Co. from whom we expect to get Japanese zirconium. We expect to get zirconium sponge under our new contracts for about $6 to $7 a pound, instead of about $12 as at present.

The companies who have these contracts, in addition to putting in enough facilities for carrying out the naval program, are also putting in capacity to take care of anticipated civilian reactor needs. We paid $300 a pound for sponge when we started out in 1948. It was only available in gram quantities at that time.

Senator BRICKER. What are the civilian uses?

Admiral RICKOVER. In addition to reactor use, it is used in the electronic industry for clearing out air and gases and so on in electronic equipment. It certainly will be used in civilian atomic powerplants, because a number of the organizations who are designing atomic powerplants are using zirconium as a basic construction material.

It also should find considerable use in the chemical industry because zirconium is much less corrosive than stainless steel at higher temperatures. It is far better.

Representative DURHAM. Does your program take the entire production from the companies you mentioned?

Admiral RICKOVER. It is currently taking nearly all of the entire production. But, as I said, the new companies are installing capacity to meet the naval requirements, and also other reactor requirements, as well as various commercial uses. But we are paying for our requirements. The other people who are designing reactors which use zirconium have not put up any money, as far as I know, to get the zirconium they will need. The Navy has put up its own money for this. The money comes from naval construction funds.

Representative DURHAM. In other words, the civilian reactors cannot depend on this production.

Admiral RICKOVER. These companies are building more capacity than is needed for the naval plants, so there should be zirconium available for civilian reactor plants.