EVALUATION OF THE PIRELLI UNDERWATER OXYGEN BREATHING EQUIPMENT FOR USE IN THE NAVAL SERVICE

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Navy Experimental Diving Unit
Washington, D. C.

28 January 1952

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NAVY EXPERIMENTAL DIVING UNIT
WASHINGTON NAVY YARD
WASHINGTON, D.C. 20390

28 JANUARY 1952

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OBJECT:

The object of this test is to evaluate the Italian equipment, known as the Pirelli for possible use by the Naval Service. The tests on the "Pirelli" to be similar to those used in the evaluation of the existing oxygen outfits. The auxiliary equipment to be evaluated for general comfort and useability.

DESCRIPTION OF UNITS:

The "Pirelli" self-contained oxygen underwater breathing apparatus is manufactured in two sizes which are identified as the "Large Pirelli", Model S-901 and the "Small Pirelli", ("Sportsman), model S-701.

"LARGE PIRELLI" (Model S-901):

The "Large Pirelli" unit is a self-contained shallow water diving and swimming outfit consisting of a face mask with mouthpiece, single breathing tube and absorbent cannister, connected to two (2) gas bottles and breathing bag. A circular cannister of 1700cc capacity is incorporated inside a 16.7 liter breathing bag which hangs in front. This feature of the Pirelli unit is similar to the British "Varbell" unit as evaluated in E.D.U. report no. 4-51. The two gas bottles, located in front at the waist contains pure oxygen and delivers it to the breathing bag via a reducer with an adjustable metering supply valve; and hand operated bypass for increased gas supply. A combination bottle pressure and depth gauge is mounted adjacent to the reducing valve. The breathing system is of the "Pendulum" type, i.e., inhalation and expiration occur through the same tube. The "Pirelli" is made of smooth rubberized material. Two (2) types of face masks are provided with the Large "Pirelli" one of which is manufactured with a neck seal and phonic box for use in cold or contaminated water (enclosure (1)). The other face mask, model S-711, is of the conventional face seal type. Both masks are equipped with mouthpieces.

"SMALL PIRELLI" (Sportsman), Model S-701:

The small "Pirelli" unit is a self-contained shallow water diving and swimming outfit, designed especially for sport fishing, consisting of a face mask with mouthpiece, breathing tube and absorbent cannister, connected to a single gas bottle and breathing bag. A circular cannister of 525cc capacity is incorporated inside the 8.9 liter breathing bag which hangs in front. The single gas bottle, located in front at the waist, contains pure oxygen and delivers it to the breathing bag via a trigger-operated bypass valve. The breathing system is of the Pendulum type similar to the Large "Pirelli". The Small "Pirelli", model S-701, is manufactured of the same smooth rubber material used in the Large "Pirelli", model S-901. The single face mask, model S-711, provided with this unit is equipped with an optional snorkel attachment for surface swimming on atmospheric air. A lever arrangement is provided which automatically closes the oxygen breathing tube when the snorkel is used. Enclosure (2) is a photograph of this unit, showing the S-711 face mask with and without snorkel attachment.

AUXILIARY UNITS AND EQUIPMENT:

In addition to the above major units, several auxiliary units were received for evaluation. They were:

1. Snorkel mask, model S-711/A, which is similar in construction to the model S-711 mask used on the Small "Pirelli" except that this mask is used solely for surface swimming and has no oxygen supply. Enclosure (3) is a photograph of this unit.

2. Goggle mask, model S-721.
This unit is a simple face mask which covers the swimmers eyes and nose for surface swimming. Enclosure (3) is a photograph of this unit.

3. Gum Rubber Swim Suit, model #751.
This is a two piece form fitting gum rubber swim suit which covers the entire body except for the head and hands. The top piece makes a water-tight seal at the neck and the top and bottom pieces are over-lapped at the waist and rolled over a special molded rubber hoop which provides the water-tight seal at this point. These suits were provided in two sizes, large and medium.

4. Gum Rubber Swim Suit, Model #752.
This accessory is exactly similar to the model #751 described above, except that it has elbow length sleeves and knee length trousers.

5. Diving Dress, Model #801.
This dress is not a swimming outfit, but rather a shallow water diving dress to be used with the Large "Pirelli." It is a one-piece dress, manufactured of rather heavy black rubberized canvas. Entrance is thru the front. A special circular wooden block and draw string is used to make the front closure as in the gum rubber swim suits a neck seal is provided.

6. Wrist Depth Gauge:
The wrist depth gauge provided has a range of 0-30 meters with one meter graduations and numerals are all luminous. Enclosure (6) is a photograph of this gauge.

PROCEDURE:

All dives were made in the wet pressure tank at the Experimental Diving Unit by experienced E.D.U. divers and were so controlled to be of an identical nature. All swimming runs were made in the indoor swimming pool at the U.S. Naval Receiving Station, Anacostia, by the same experienced E.D.U. personnel and were also of a controlled nature. In all tests, the "Pirelli" units were used without any modifications.

(a) DEPTH OF DIVES:

Dives were made in both the Large and Small "Pirelli" units at surface (7 feet), 15 and 30 foot depths. All divers engaged in evaluating this equipment were required to make a familiarization dive at 7 feet of water for 15 minutes duration. After this indoctrination, nine (9) dives in the Large "Pirelli" of 30 minute duration were made at the 15 foot depth followed by ten (10) dives at 30 feet of 30 minutes duration and another three (3) dives at surface depth of 120 minutes duration, all with the Large "Pirelli." Upon completion of these dives two endurance runs were made to determine the length of time the unit could be used under the conditions imposed by these tests before either cannister or bottles became exhausted. In a similar manner using the Small "Pirelli" the following dives were made in addition to the familiarization dives:

(a) Four (4) dives of 30 minute duration at 15 feet.
(b) Two (2) dives of 30 minutes duration at 30 feet.
(c) Two (2) endurance runs at surface (7 feet).

All dives were work dives in which controlled moderately heavy work was accomplished. Five (5) minute rest periods were alternated with each ten (10) minute work period so that the diver would rest five (5) minutes, work ten (10) minutes, rest five (5) minutes, work ten (10) minutes, etc. The apparatus was purged prior to use by each diver by exhaling five breaths to the atmosphere.

(b) SIMULATED WORK:

Moderately heavy work was simulated by the lifting of a 68.5 pound weight back and forth from the deck of the tank to a work bench 27 1/4 inches high.

(c) THE BREATHING MEDIA:

Oxygen was supplied from two (2) high pressure bottles each with a capacity of 1.73 liters in the case of the Large "Pirelli" and a single high pressure bottle of .62 liter capacity in the Small "Pirelli." All bottles are capable of being charged to two (200) hundred atmospheres (2940 psi) and are so certified by the Italian Railway Club.

(d) GAS SAMPLES:

Samples for CO2 and O2 analysis were taken through a sample tube connection installed near the top of the Pendulum breathing tube. All samples were taken two (2) seconds after the beginning of an inspiration and the sample drawn continuously throughout the inspiration by means of a Luer syringe. Since it is practically impossible to obtain a true representative CO2 sample in a Pendulum breathing apparatus because of the varying rates of gas flow and gas content during the inspiratory phase, sampling was carefully controlled in order to obtain the most accurate samples possible. During the evaluation of both the Large and Small "Pirelli" samples were taken immediately after purging, and after each work period. A tabulation of results are shown on the data sheets.

(e) GAS FLOW:

The divers oxygen supply on the Large "Pirelli" is controlled by the diver by means of a regulator with bypass. This is a special pressure reducer which permits a constant gas flow to the breathing bag, which, according to the manufacturer, is adjustable within the range of 0.5 - 3.5 liters per minute by its connected butterfly handle. The valve assembly has a bypass which permits, by pushing the lever, a supplementary or emergency gas flow to the bag. Thus an experienced diver or underwater swimmer by carefully adjusting his gas flow can obtain very nearly automatic 02 supply and needs only to use the bypass lever occasionally to increase the breathing bag volume. The gas flow on the "Small Pirelli" however, is not regulated in this manner, but rather is accomplished by means of a lever bypass. Thus, gas flow on the Small "Pirelli" is not in any sense automatic but is manually controlled by the diver or swimmer to meet his oxygen requirements.

(f) BOTTLE CAPACITY:

Bottle pressure was measured before and after most dives and total pressure recorded. The bottles were never charged to their full capacity of 3000 psi, but usually between 1500 - 1700 psi.

(g) BREATHING RESISTANCE:

Peak or maximum inspiratory and expiratory pressures were determined for both "Pirelli" units (out of water at atmospheric pressures) using the Mine Safety Appliance Company breathing resistance testing apparatus operated at 15 cycles per minute with a stroke volume of 0.075 cubic feet. These measurements were made on "closed circuits: and "surface breather" for both outfits. In the case of the Small "Pirelli" the snorkel was included in the "Surface breather" measurements. Enclosures (7), (8), and (9) are photographs of the equipment used.

(h) UNDERWATER BREATHING RESISTANCE:

A special laboratory setup was developed in an attempt to determine peak inspiratory and expiratory pressures with the outfits submerged in water and invarious submerged positions. The purpose of these tests was to determine, if possible, a comparison between peak pressure measured out of water at atmospheric pressure and the same pressures with the apparatus submerged and rotated in various angles of inclination. A special supporting form for the apparatus was constructed in such a manner that the entire apparatus could be rotated while submerged. Initial experimentation clearly indicated that the submerged respiratory pressures and in particular, peak expiratory pressure were greatly increased over measurements made with the apparatus out of water. It was also noted that the angle of inclination of the apparatus caused a varience in peak pressure measurements. However, with the equipment presently available for conducting such experimentation, it is impossible to compare our submerged results with the atmospheric measurements, and no

attempt was made to do so in this evaluation. It is expected that with procurement of the proper equipment and further experimentation a means of directly comparing atmospheric and submerged respiratory pressures can be developed. Additional work on this problem will be accomplished.

(i) ANGLE OF VISION:

The horizontal and vertical angles of vision were measured by having various subjects face a blank wall and measuring the subtended angle.

(j) DEAD AIR SPACE:

Since all "Pirelli" masks utilized a mouthpiece only the Pendulum breathing tube and mouthpiece represented the major dead air space. The volume of this tube was determined by filling the tube and mouthpiece with water and measuring the water so required.

(k) SWIMMING TESTS:

In addition to the dives made in the Experimental Diving Unit wet tank, twelve (12) actual swimming runs were made in the Receiving Station indoor swimming pool by E.D.U. personnel wearing the Large "Pirelli" and six (6) swimming runs wearing the Small "Pirelli." The purpose of these swimming runs were to evaluate the general underwater swimming characteristics of the Pirelli equipment. In order that the swimmers using this equipment for the first time would not form a biased opinion, it was required that they make a comparison swimming run of identical nature using another type of equipment. All swimming runs were sub-surface the depth being dependant on the depth of the pool. Water temperature was approximately 70°F during the evaluation. On several runs the "Pirelli" rubber swim suit was worn for a rough comparison with other types of swim suits. Several of the personnel utilized in this evaluation were former UDT swimmers who had as much as three (3) years experience with all types of self-contained underwater breathing apparatus and their comments were considered especially valid in the swimming evaluation. All swimming rates were controlled at approximately one knot and a run lasted until the swimmer became exhausted or was forced to terminate the run (because of a mechanical failure of the equipment).

(l) GUM RUBBER SWIM SUITS:

These suits have been worn by various E.D.U. personnel on several occasions but formal evaluation has been delayed pending arrival at the E.D.U. of various other types of swim suits. The "Pirelli" suits will be formally evaluated with other suits of a similar nature.

(m) WRIST DEPTH GAUGES:

The gauges supplied with this outfit were tested for accuracy by submerging them in a container of water and subjecting them to increase pressure in the E.D.U. recompression chamber. The underwater readability was evaluated by having a diver wear the gauge during a dive in the wet tank.

RESULTS AND DISCUSSION:

PRELIMINARY TESTS:

Upon receipt of the "Pirelli" outfits a careful check was made of all units and auxiliary equipment to familiarize the Experimental Diving Unit personnel with the physical characteristics of the equipment and the method of using the outfit. Several dry runs were made by dressing a number of divers to get the "feel" of the unit.

Prior to making any wet dives the gas flow through the regulator was checked by means of the large spirometer. Two (2) such regulators on the Large "Pirelli" were so checked with the butterfly regulator on the "A" or open position. The gas flow was found to be 0.9 and 2.4 liters respectively. The test was repeated with the regulator in the "C" or closed position. Flow was found to be 0.4 and 0.7 liters per minute. Since these values did not in any way correspond to the manufacturer's claim of a 0.5 - 3.5 liters per minute range the entire regulator valves and by-passes were disassembled for examination. Upon disassembly the trouble was readily evident, being caused by corrosion and excess grease in the way of the metering orifices. The valves were reassembled and gas flow again determined. It was necessary to adjust the regulator several times before the proper gas flow was accomplished. However, after this final adjustment no further adjustment was required during the entire evaluation.

It was necessary to make similar checks on the Small "Pirelli" since on this outfit a high pressure spring loaded needle valve is used to permit gas flow to the breathing bag. No metering valve is used on this outfit, the needle valve being operated by depressing a hand lever. No additional discrepancies were noted at this time.

PART I

EVALUATION DIVES (LARGE PIRELLI):

Thirty-seven (37) controlled dives were made wearing the Large "Pirelli" at depths varying from surface (7 feet) to thirty (30) feet. All dives were made in the E.D.U. wet pressure tank with the water temperature maintained at approximately 80 - 85 degrees F. Except for several familiarization dives during which the rubber swim suits were worn, all other dives were made in swim trunks. No additional weights were required or worn during this evaluation. Soda lime was used as the CO2 absorbent throughout the evaluation. During the familiarization dives the absorbent was changed after each dive but on subsequent dives, except on endurance runs, was changed after each two (2) hours of use. As is readily shown on the data sheets, the CO2 concentration never reached a dangerous level on any dive with the exception of dive number 37, during which CO2 concentration reached a value of 3.87%. However, dive number 37 was the final dive of the endurance run to determine maximum cannister life and was therefore, to be expected. The 3.876% CO2 value was reached after five (5) hours and twenty-five (25) minutes of diving time at which time the diver noted definite evidence of excessive CO2. This was the only dive during the entire evaluation that a diver noticed effects of increased CO2 concentration while using the Large "Pirelli.: Gas samples were all analyzed on a Haldane apparatus immediately after the sample

was taken. The accuracy of the gas analysis is considered more than adequate but the actual process of sampling involves several variables which make representative sampling on this type of apparatus extremely difficult. The following variables are considered to have major effect on the resulting sample analysis:

(a) Inspiratory phase at which sample is actually taken.
(b) Volume of gas in the breathing bag at the time sample is taken.
(c) Tendency of divers to inflate breathing bag with fresh oxygen prior to the sample being drawn in order to fully inspire while sample is being taken. Since samples are taken after a work period the volume of oxygen in the breathing bag is usually somewhat decreased so that this is a very natural tendency.

In view of these variables, especially the addition of fresh gas, it is probable that the CO2 concentration immediately at the end of a work period is somewhat greater than would be indicated by the values shown on the data sheets. It is anticipated, however, that upon receipt of our Liston Becker continuous reading CO2 analyzer the problem of sample variation will be corrected.

The oxygen concentration during all evaluation dives was maintained at fairly constant values. After pruging, the oxygen percentage at atmospheric pressure ranged on the average from 70 to 90 percent. Several low readings in the range of 45 - 50 percent were recorded, which undoubtedly were a result of inadequate purging prior to going on "closed circuit." In general, however, purging appeared to be adequate and no dangerously low readings were encountered. At the depths encountered in this evaluation, oxygen partial pressure never increased to a dangerous value for the exposure times utilized, and no symptoms of oxygen toxicity were noted.

EVALUATION DIVES (SMALL PIRELLI):

The Small "Pirelli", model S-701, is not intended as a diving apparatus but was designed rather as a sport fishing outfit. It is a lightweight unit having a small air flask and absorbent capacity. For this reason only a relatively few dives were made in the wet tank with the apparatus. In all twelve (12) dives were made under the identical conditions utilized in the evaluation dives for the Large "Pirelli" described previously. Gas sampling was also conducted in an identical manner and the same observations hold on this apparatus as were made on the Large "Pirelli."

From a persual of data sheets number 6 - 8 it is clearly evident that in none of these evaluation dives did the CO2 concentration reach a dargerous

level and that the oxygen percentage remained fairly constant. The oxygen range was practically the same as that determined on the Large "Pirelli", i.e. 70-90 percent. The CO2 concentration, however, are on the average slightly higher than those determined on the larger apparatus. The increased CO2 concentrations developed in the small apparatus are probably due to the increased rate of gas flow through the cannister and the small amount of absorbent utilized in the cannister (525cc).

Two surface endurance dives were made to determine the continuous length of time the unit could be used and whether the oxygen bottle (gas supply) or cannister (CO2 absorbtion) was the limiting factor. On both these runs the oxygen flask was charged to 1800 psi. Both dives were terminated after one (1) hour and fifteen (15) minutes due to exhaustion of the oxygen supply.

DURABILITY OF "PIRELLI" APPARATUS:

In conducting this evaluation, the "Pirelli" apparatus was in constant use over a three (3) month period. In all, the units were donned and used approximately one-hundred and fifty (150) times either for diving or swimming tests. Many of the dives were strictly for the purpose of familiarization for new personnel with no samples being taken, or for some specific purpose where the taking of samples was impracticable. Although four (4) conplete units, both large and small, were received the entire evaluation was conducted with two (2) units of each model with the exception of several items which were prone to early failure. Thus, the Experimental Diving Unit has had an excellent opportunity to observe and evaluate the durability of this apparatus under ideally controlled conditions.

In general the "Pirelli" is a fairly durable apparatus, if given careful preventative maintenance at regular intervals. It has, however, several mechanical defects and weak points which in spite of careful handling are prone to be troublesome and subject to early failure. In all fairness it must be stated that in practically every instance, failure or defective operation of a component was due to inferior material used in its manufacture rather than to a faulty design. The mechanical defects noted and components which are prone to early failure are listed as follows:

(a) Mechanical Defects:

1. The glass in three (3) face masks of the neck seal type model cracked in normal use very shortly after arrival. The glass face piece was replaced with plexiglas which has proven completely satisfactory.

2. The hinged face plate on the above mask is unsatisfactory due to the early failure of the rear supporting ring. This ring, which is

manufactured from an inferior brass alloy, does not have sufficient strength or rigidity for the stress applied when the face plate is closed against the rubber seal. These rings have a tendency to bend due only to the pull of the fasteners in securing the face plate. Thus an ineffectual seal is accomplished and leakage around the face plate boundary results. This defect was noted on both masks early in the evaluation and an attempt to straighten the rings resulted in complete facture of the ring. The broken rings were satisfactorily repaired by silver soldering and returned to service. However, subsequent failures have occured at other points on the ring with the result that constant repairs are required and for this reason the use of the neck seal type mask has been greatly curtailed and the Model S-711 face mask substituted. The model S-711 face mask is identical to the above mask except that it does not have a hinged face plate neck seal or phonic box.

3. The waterproof bottle gauge is entirely unsatisfactory from a material standpoint. Three (3) of the four (4) gauges received have already failed in service. Two (2) gauges failed as a result of porous material which developed pin hole leaks. On one guage this leak occured on the inside of the guage which permitted excessive pressure to build up within the guage and resulted in the guage exploding. The third (3) guage failed as a result of fracture of the guage securing threads. Enclosure (10) is a photograph showing two (2) of the failed guages.

4. Early failure of the securing lip of the breathing tube-cannister fitting on one unit. Failure dur to complete fracture of the lip, and again a result of inferior brass alloy. Repaired by silver soldering.

5. Early leakage encountered around the bolt holding the breathing tube connection on the cannister. Leakage due to stripped cannister threads. Again a material failure.

6. Failure of the thin rubber neck seal on one face mask after very limited use. This failure was caused by attempting to stretch the material by the prescribed method over a fairly large head. Without doubt excessive pull was exerted on the thin rubber material causing it to tear out. However, it does appear that an inferior grade of rubber is used for this very rugged applications.

7. In order to remove the circular cannister from the rubber breathing bag it is necessary to stretch the rubber opening an appreciable amount. On one of the Small "Pirelli" units the first time the cannister was removed the rubber breathing bag material tore quite badly due to the application of excessive pressure in removing the cannister through the small hole. This is, of course, more of a design failure than a material failure and is easily corrected by a very slight enlargement of the cannister opening.

Except for the mechanical defects noted above, the remaining components appear quite durable and functioned in an entirely satisfactory manner. All components are readily accessible for repair, disassembly and leak detection.

The combination reducing, regulating, and bypass valve appears to be rather more complicated than necessary being made up of thirty-six (36) separate pieces or parts. However, this three-way valve appears to be very durable since after making the original adjustment no further maintenance or repairs were required during the entire three (3) month period. However, from gas flow determinations made at the end of this period it was found that the rate of flow through the regulator had decreased from the original value of 3.5 liters per minute to 2.9 liters per minute. Upon disassembly of the valve appreciable corrosion was evident but after cleaning all parts thoroughly and reassembling, the original flow values were obtained.

All face masks received with the exception of the neck seal mask having the hinged face plate previously discussed appear to be extremely durable. They are constructed for rugged service and required no repairs or unusual maintenance.

The oxygen bottle valves had a slight tendency to leak after continued use but the leaks were readily stopped with the installation of new washers.

COMFORT OF "PIRELLI" APPARATUS:

The overall comfort of the "Pirelli" apparatus is quite good when compared with all types of SCUBA's evaluated by the E.D.U. When compared with SCUBA's which incorporate the use of a mouthpiece it is without doubt the most comfortable apparatus evaluated. The lightweight, exceptionally comfortable fit of the face mask, good visibility, the ease with which the gear can be put on and taken off, and the balance of the apparatus are all good features. No additional weights are required to control buoyancy, which is adequate. All E.D.U. divers were particularly enthusiastic with the fit and comfort of the face mask. A good face seal is possible on a variety of facial contours with a minimum head strap tension so that the mask could be worn for several hours without noticeable discomfort. The wide head strap is not as satisfactory as the multiple strap head harness since the mask has a tendency to slip forward on the head when using the wide head strap. Although the face mask makes an excellent face seal the use of the nose clip is definitely required because of a rather high exhalation resistance and tendency to build up a positive pressure within the mask. The nose clip supplied with this apparatus has excessive spring tension and tends to become very uncomfortable after a very short time.

The hooded neck seal mask is by far the least comfortable of the masks for the following reasons:

(a) Oxygen escaping from nose or around mouthpiece (result of rather high breathing resistance) collects in hood. Theoretrically this excess air can be expelled through the two flutter valves under the chin, however, it was found that these flutter valves had a tendency to stick closed and as a result were seldom operable.

(b) It is practically impossible to expell water from mask when submerged. This is true of all "Pirelli" masks to some degree since no water-expulsion valve is provided on any of them.

(c) Excessive fogging of faceplate. The most effective means of cleaning the faceplate of a mask is to "wash" it with a small amount of water, present or admitted for the purpose. It is virtually impossible to admit a small amount of water to the "Pirelli" mask, and the admission of an excessive amount may lead to trouble due to difficulty of expulsion.

(d) Phonic box is too close to nose and in some instances touches. The mouthpiece tube in all of the masks is too long and has a tendency to buckle, especially when head is depressed. This causes an almost complete obstruction and increase breathing resistance tremendously.

The "Pirelli" mask when fitted with the Snorkel (sportsman model) appears to have more disadvantages than advantages and in the opinion of this activity is unsatisfactory. However, the idea has decided merit and an improved and satisfactory snorkel would be a definite asset for certain type of operations. The major objections to this particular apparatus are as listed below:

(a) Breathing resistance through snorkel definitely objectionable due mostly to airway resistance.
(b) Submersion valve is inadequate in that positive closure is frequently not accomplished as a result, inspiration of water may occurr with obvious dangers. The means provided for expelling water from the snorkel tube does not function adequately so that water admitted in this manner must either be swallowed or expelled around the mouthpiece into the mask where it will remain. Any water left in the mouthpiece or valve will automatically enter the cannister upon shifting to re-breathing circuit.
(c) Possibility of excessive CO2 buildup in snorkel tube.

The Breathing bags and oxygen flasks are well ballanced and comfortable to wear. Even after dives of two (2) hours duration no discomfort was noted. However, the oxygen bottle valves extend outward an excessive distance and have a tendency to hit the divers legs or knees when working in a crouched position, but do not interfere with swimming. The limited gas capacity of the Small "Pirelli" breathing bag at times prevents taking a full inhalation, especially under conditions of hard work.

BREATHING RESISTANCE OF "PIRELLI" APPARATUS:

The breathing resistance of the "Pirelli" apparatus was determined by the identical method used to determine breathing resistances on previously evaluated apparatus. As in previous determinations of the Mine Safety Appliance Respiratory Resistance Machine was used to supply a constant tidal volume of air. The tidal volume used was .075 cubic feet for a pulmonary ventilation of approximately 32 liters per minute. The results obtained are as tabulated on the next page.

I. LARGE PIRELLI

Bag lying on table - approximately one-half full at mid point of respiratory cycle. Cannister full - 15 cycles per minute, bellows delivering 2122 cc/stroke.

A. Valve turned to Breathing Bag:

RUN NO.	PEAK INSPIRATION PRESSURE INCHES OF WATER	PEAK EXPIRATION PRESSURE INCHES OF WATER
1	2.52	2.60
2	2.52	2.68
3	2.52	2.60
4	2.52	2.60
Ave	2.52	2.62

B. Valve turned to Surface Breather:

1	2.13	2.52
2	2.05	2.48
3	2.13	2.60
Ave.	2.10	2.53

C. Increased volume of air in bag - bag full:

1	2.05	3.31

II. SMALL PIRELLI

Bag lying on table - approximately one-half at mid point of respiratory cycle, cannister full - 15 cycles per minute. Bellows delivering 2122 cc per storke.

a. Valve turned to breathing bag - forced full open

PEAK INSPIRATION PRESSURE INCHES OF WATER	PEAK EXPIRATION PRESSURE INCHES OF WATER
2.6	2.76

B. Some air removed from bag:

2.68	2.83

C. Valve turned to notch for re-breathing (bag)

6.06	5.63

D. Valve turned to snorkel position:

2.36	2.83

From the above data it is obvious that the breathing resistance of both the Large and Small "Pirelli" units is appreciably greater than the overall average resistance of 1.74 inches of water reported for the Lambertson, Browne, and MSA in the E.D.U. report no. 1-50. This is true of both when operating on closed circuit (oxygen rebreathing) and on surface breather. The fact that "bag" and "surface" breathing resistances were almost the same in the Large "Pirelli" provides evidence that most of the relatively high breathing resistance can be attributed to the mouthpiece and the valve itself. The small internal diameter of the valve is without doubt the contributing factor. It seems likely that the resistance is due not only to constriction of the airway, per se, but also to the tendency of such a change in airway diameter to cause turbulent air flow with consequent increased resistance. The effect of a restricted airway is also evident in the results obtained on the Small "Pirelli" with snorkel attachments with valve turned to notch for rebreathing (part C). It is obvious that the "notch" where the valve snaps into position when turned to oxygen rebreathing circuit does not represent a full opening, since forcing the valve handle beyond this point greatly reduced the inspiration and expiratory pressures to normal values. This difficulty is related to the mechanism by which the upper end of the snorkel is automatically closed when the valve is turned to the rebreathing position.

ENDURANCE OF THE "PIRELLI" APPARATUS:

As discussed previously, endurance dives were made on both the Large and Small "Pirelli" apparatuses to determine the length of time the apparatus could be used on a continuous operation before either exhaustion of gas supply or absorbent caused termination of the dive. The results of these endurance runs were as described below:

A. LARGE "PIRELLI"

An initial four (4) hour endurance run failed to exhaust either gas supply or CO2 absorbent but did give definite evidence that the absorbent would be the controlling factor since less than one-half (1/2) the available oxygen supply was utilized in this run (assuming both bottles charged to full capacity of 3000 psi). CO2 percentages, however, toward the end of the fourth hour were noted to be increasing slowly. Therefore a second endurance run was made and continued until the CO2 absorbent was exhausted. (Dive no. 37 CO2 percentage 3.876). CO2 samples were taken every 15 minutes and divers changed hourly. Upon emptying the cannister about one-half the soda lime absorbent was found to be discolored. From a persual of data sheet no. 5, it can be seen that the atmospheric CO2 concentration had reached a value of 1.247 percent at the end of 4 1/2 hours. It is the opinion of this activity that this is the practical end point of the endurance run since an increase in depth to 30 feet at this point gives an effective CO2 percentage of 2.38%.

It was clearly demonstrated by this endurance run that the "Pirelli", model S-901 is the only SCUBA so far evalueated by the E.D.U. in which breathing media supply greatly exceeds cannister life. In all other SCUBAs gas supply was the controlling endurance factor. The cannister used in the Large "Pirelli" is incorporated inside the breathing bag and is of a radial type. The cannister has an absorbent capacity of 1700 cc with a breathing bag volume of 16.7 liters. Each 02 flask has a capacity of 1.73 liters and can be charged to a pressure of 3000 psi.

B. SMALL "PIRELLI"

Two surface endurance runs were made with the Small "Pirelli" in the same manner as the Large "Pirelli: described above except that a single diver made the complete run. Both runs were terminated at the end of one (1) hour and fifteen (15) minutes due to exhaustion of the gas supply. The single oxygen flask was charged to 1800 psi prior to each run. From an examination of data sheet no. 8, it can be seen that in both these runs the C02 consentration was beginning to increase. Therefore, it is difficult to say with assurance that, had the flasks been fully charged to 3000 psi, the results would have been the same. It is entirely possible that under these conditions the cannister may have been exhausted first. However, for all practical purposes the gas supply will control duration, since facilities will not ordinarilly be available to charge the flask to 3000 psi.

The cannister used in the Small "Pirelli" is identical to that used in the Large "Pirelli" but is of a smaller size. It has an absorbent capacity of 525 cc with a breathing bag volume of 8.9 liters. The flask capacity is .621 liters. The cannister used on this outfit is quite difficult to fill because of the very small diameter of the filling neck.

MASK DEAD AIR SPACE:

Since both "Pirelli: units require the use of a mouthpiece the air space within the mask should not be considered in the determination of effective dead air space. The components which contribute to the effective dead air space in this type of apparatus are:

(1) breathing tube
(2) mouthpiece and fitting
(3) cannister fitting
(4) some presently indeterminate portion of the cannister itself.

Thus, for the present evaluation only the first three (3) items were considered, these having a total of 140 cc on both "Pirelli" outfits.

There is reason to believe that the effective dead space may be greater or smaller than these measurable volumes. It is also apparent that in a pendulum system when some of the absorbent becomes exhausted the portion of the cannister which it occupies will add to the effective dead space to some degree.

ANGLE OF VISION:

The angle of vision was found to be practically the same for all "Pirelli" masks received. These angles were determined to be 100 degrees laterally and approximately 91 degrees vertically.

WRIST DEPTH GAUGES:

A study of the data listed on data sheet No. 9 indicates that in general these depth guages are fairly well calibrated and are considered satisfactory for the purpose intended. Under increasing pressure all guages read on the low side to a depth of 60 feet. From 60 feet to 99 feet six (6) guages continued to read low, and two (2) guages read high. However, on decreasing the pressure all guages except guage no. 5 had a tendency to give reading which were slightly high. Gauge no. 5 was found to be defective as a result of water entering the gauge mechanism by way of a broken face glass. Gauge no. 8 failed to operate until a depth of 33 feet was reached under increasing pressure, probably due to a stuck needle mechanism. However, this gauge functioned satisfactorily thereafter. The gauges are accurate within 1 to 2 percent throughout the range, which is excellent for this type of gauge.

The luminous dial marking and needle are sufficiently large to be easily readable under normal conditions of visibility and the gauges are also considered entirely satisfactory in this respect. Enclosure (11) is a photograph of the wrist gauge.

PART II

SWIMMING EVALUATION OF THE "PIRELLI" APPARATUS:

A total of eighteen (18) swimming runs were conducted with this apparatus, twelve (12) using the Large "Pirelli" and six (6) using the Small outfit.

In general the underwater swimming characteristics of both outfits were considered to be very good and all personnel using the gear had many favorable comments. The Large "Pirelli" was much preferred to the Small sportsman model which was to be expected in view of the information gained from our evaluation dives.

The very good balance of the apparatus which does not require the use of additional lead weight is an expecially fine characteristic as is the comfortable fit of the face mask (not considering the mouthpiece).

The swim suit when used with the "Pirelli" apparatus was very satisfactory and well liked by all swimmers and from the very limited observations made at this time, appeared to produce very little increased resistance to swimming.

A summary of the advantages and disadvantages of this apparatus determined as a result of the swimming evaluation are listed below. Most of these observations have appeared previously in this report.

A. ADVANTAGES:

1. Excellent balance of the apparatus.
2. Long endurance of gas supply.
3. Offers little resistance to swimming when compared with other SCUBA.
4. Comfortable fit of face mask and swim suit.
5. Convenience and ease of operation of bypass.
6. Ability to regulate gas flow in relation to energy output.
7. Good visibility and wide angle of vision.

B. DISADVANTAGES:

1. Difficult to expell excess air from neck seal mask at any time and from other masks while submerged.
2. No excess pressure valve on breathing bag. Excessive gas build-up in bag and face mask when depth is decreased. Even experienced UDT swimmers had difficulty in remaining submerged while decreasing depth.
3. Spring tension of nose clips too great and become very uncomfortable after even a short time.
4. Inability to drop mouthpiece and breath through mask when submerged. This is possible on surface, but due to increased submerged breathing, resistance cannot be done while submerged, also mouthpiece has a tendency to buckle.
5. Surface breather orifice is too small for low resistance breathing.
6. Bottle pressure gage difficult to keep in proper position due to curring threads deeper each time it is replaced after charging bottles. Also bottle valves tend to leak for the same reason. Both defects due to use of inferior brass alloy. On one occasion, before this defect was noted, leakage into the breathing bag caused the bag to become over inflated which resulted in the rupture of a seam.
7. Snorkel breathing tube generally unsatisfactory for reasons noted previously.
8. No adequate means of expelling water from mask, especially when submerged.

CONCLUSIONS:

In general the evaluation of the "Pirelli" was very satisfactory and much valuable information was gained. The performance of the Large "Pirelli" was excellent in many respects, and was generally well liked by all E.D.U. personnel from a performance standpoint. The performance of the Small "Pirelli" did not prove nearly as satisfactory and has but very limited value. The following specific conclusions are based entirely on the results of this evaluation:

1. The comfort and endurance of the "Pirelli" apparatus is excellent. The endurance of the Large "Pirelli" is four and one-half (4 1/2) hours under conditions of moderate work with an average oxygen consumption of .875 liters per minute. The endurance determinations were terminated by excessive CO2 build-up rather than exhaustion of gas supply. This apparatus is the only SCUBA so far evaluated by the E.D.U. wherein endurance is not limited by gas supply.

2. The oxygen flasks when fully charged have an endurance in excess of nine (9) hours when used under the conditions imposed by this evaluation (average 02 consumption of .875 liters per minute).

3. All dives made in this apparatus were successful and gas levels fall well within safe limits for diving at these depths.

4. The out-of-water atmospheric breathing resistance of the "Pirelli" apparatus, (when determined by the method used in previous evaluations) is greater than that reported for the Lambertson, MSA, and Browne apparatus (report no. 1-50). The breathing resistance of this apparatus increases appreciably when submerged and in some submerged positions is excessive.

5. In spite of a measured capacity of 8.9 liters, the breathing bag of the Small "Pirelli" did not appear to have a great enough effective capacity to accomodate the larger tidal volume of respiration which developed with exertion. There were no complaints of this nature with the Large "Pirelli."

6. Both "Pirelli" outfits have very nearly neutral buoyancy. No additional weights are required.

7. The wrist depth guages received with this equipment are quite satisfactory in respect to accuracy and readability. No conclusions can be made in regard to durability. One guage failed as a result of not being water proof.

8. In general all brass fixtures or components are of inferior quality and prone to early failure. The following items are unsatisfactory: (1) water proof bottle guages (2) hinged face plate, (3) bottle valves, (4) cannister fittings, and (5) breathing tube fittings.

9. The face masks are not equiped with means for water expulsion since the surface breather is unsatisfactory for this purpose when submerged.

10. The breathing bag openings through which the cannister is inserted are too small and should be enlarged.

11. The breathing bags do not incorporate the use of an excess pressure valve and have a tendency to over inflate when water pressure is decreased.

12. The two neck flutter valves on the hooded face mask were inoperable most of the time. As a result, excessive gas collected in the hood and face mask which was difficult to expell.

13. The snorkel attachment on the Small "Pirelli" was generally unsatisfactory because of (1) increased breathing resistance, (2) faulty operation of the valve and lever mechanism used to shift from breathing bag to snorkel, and, (3) inadequacy of the submergence float to prevent entry of water.

14. The three way control valve was satisfactory in all respects and is an excellent regulator, although it appears excessively complicated for field maintenance.

SUMMARY:

In fundamental design, the Large "Pirelli" Model S-901, is of a simple and very familiar type. The only really unique feature appears to be the constant flow valve with trigger bypass, and this proved satisfactory and desirable. However, it is the opinion of this activity that the combined Airco regulator and demand valve incorporated in a SCUBA presently being evaluated will be equally satisfactory and much less complicated.

The oxygen supply provided is exceptionally ample and the ability of the unit to absorb CO2 is at least as good as that of other underwater breathing apparatus of similar type which has been tested.

Basically the "Pirelli" mask leaves little to be desired. Non-essential features such as the hinged face-plate and hood of the more elaborate model introduced difficulties, and a water expulsion valve would be a very desirable addition; but the most serious objection, the absolute necessity of using a mouthpiece, is not a fault of the mask, but rather a fault of the Pendulum breathing system and high expiratory pressures.

Several machanical failures occured, but it is our opinion that they could have been prevented by use of a better brass alloy and do not represent faulty design.

Extensive use within the limits of the evaluation procedure employed failed to reveal any serious deficiencies in the actual performance of the Large "Pirelli." It is felt that several modifications are desirable, but the unit as it stands is generally superior to others which have been investigated.

RECOMMENDATIONS:

1. That if the needs of the service require prompt procurement in limited numbers, the Large "Pirelli" (model S-901) with the Model S-711 face mask is satisfactory provided that all brass fittings be improved by use of a better brass alloy and that spare parts in adequate quantity be provided.

2. Prior to possible procurement in large numbers, the following additional modifications should be made:

(a) A water expulsion valve incorporated into the mask.
(b) A valve with larger internal diameters substituted for the present "surface-rebreather" valve.
(c) An excess-pressure valve provided in the breathing bag.

LARGE PIRELLI - MODEL #S-901 - DATA SHEET #1

Familiarization Dives - Depth - Surface - Duration - 15 Minutes. 5R-10W

Dive No	START - After Purge				FINISH			
	Actual CO2	Effect CO2	Actual O2	Effect O2	Actual CO2	Effect CO2	Actual O2	Effect O2
1	.012	.012	51.80	51.80	.049	.049	71.29	71.29
2	.121	.121	73.20	73.20	.212	.212	79.38	79.38
3	.095	.095	76.46	76.46	.072	.072	93.86	93.86
4	.022	.022	76.46	76.46	.025	.025	86.70	86.70
5	.261	.261	84.58	84.58	.023	.023	67.12	67.12

Actual CO2			Effective CO2			Actual O2			Effective O2		
Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
.261	.012	.080	.261	.012	.080	93.86	51.80	76.09	93.06	51.80	76.09

Depth: 15 feet - Duration: 30 Minutes 5R-10W-5R-10W **Factor: 1.45454**

Dive No.	After Purge - 0 Minutes				15 Minutes				30 Minutes			
	Actual CO2	Effect CO2	Actual O2	Effect O2	Actual CO2	Effect CO2	Actual O2	Effect O2	Actual CO2	Effect CO2	Actual O2	Effect O2
6	.065	.094	91.76	133.47	.113	.164	70.83	103.03	.023	.034	45.37	66.99
7	.073	.106	76.29	110.97	.092	.134	90.73	131.97	.115	.167	90.73	131.97
8	.023	.034	82.44	119.91	.124	.175	85.57	124.46	.067	.097	85.57	124.46
9	.331	.481	75.26	109.47	.117	.170	86.60	125.46	.069	.100	81.45	118.47
10	.094	.137	84.54	122.97	.083	.121	86.60	125.98	.101	.147	91.76	133.47
11	.163	.237	77.32	112.47	.110	.161	80.66	117.32	.372	.541	70.47	102.50
12	.152	.221	85.62	124.54	.173	.252	88.80	129.18	.273	.397	84.73	123.24
13	.125	.182	93.85	136.51	.088	.128	46.67	67.88	.201	.292	80.52	117.12
14	.021	.031	93.85	136.51	.191	.278	89.75	130.54	.132	.192	91.80	133.54

Actual CO2			Effective CO2			Actual O2			Effective O2		
Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
.372	.021	.133	.541	.031	.188	93.85	45.37	81.76	136.51	66.99	119.07

LARGE PIRELLI - MODEL S-901 - DATA SHEET #2

Depth: 30 feet - Duration: 30 Minutes - 5R-10W-5R-10W Factor: 1.90908

Dive No	After Purge 0 Minutes				15 MINUTES				30 MINUTES			
	Actual CO2	Effect CO2	Actual O2	Effect O2	Actual CO2	Effect CO2	Actual O2	Effect O2	Actual CO2	Effect CO2	Actual O2	Effect O2
15	.022	.040	--		.032	.061	88.68	169.38	.231	.441	88.68	169.38
16	.023	.044	86.78	165.75	.102	.195	87.80	167.70	.023	.046	87.40	166.93
17	.107	.204	83.63	159.73	.010	.019	77.49	148.01	.010	.019	89.77	171.46
18	.024	.046	83.59	159.66	.227	.434	87.70	167.51	.069	.132	85.65	163.59
19	.024	.046	84.70	161.77	.023	.044	89.80	171.52	.023	.044	89.80	171.52
20	.221	.422	81.60	155.86	.023	.044	88.76	169.53	.112	.214	88.76	169.53
21	.045	.086	80.56	153.87	.316	.604	85.68	163.65	.512	.978	83.63	159.73
22	.086	.164	78.60	150.13	.031	.059	57.19	109.23	Sample Lost			
23	.023	.044	84.71	161.80	.336	.642	82.65	157.86	.115	.221	82.65	157.86
24	.021	.040	82.80	158.15	.020	.041	85.68	163.65	.045	.088	84.65	161.68

Actual CO2			Effective CO2			Actual O2			Effective O2		
Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
.512	.010	.0985	.978	.019	.188	89.80	57.19	84.26	171.52	109.23	155.39

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DATA SHEET NO. 3

INITIAL ENDURANCE RUN - LARGE PIRELLI - SURFACE PURPOSE - TO DETERMINE CANNISTER EFFICIENCY AND COMFORT OF UNIT ON DIVES IN EXCESS OF ONE (1) HOUR DURATION

DIVE NO	SAMPLE TIME	ACTUAL CO2	ACTUAL O2	REMARKS
25	0	.339	77.49	Sample after purge.
	15 min.	.121	84.65	No discomfort noted during dive except for
	30 min.	.024	74.42	normal tiredness.
	45 min.	.070	83.63	5R - 10W sequence throughout duration of
	60 min.	.093	83.63	dive.
	1 hr.15	.216	83.63	
	1 " 30	.114	82.60	
	1 " 45	.546	82.60	
26	0	.201	79.56	Sample after purge - new soda lime absorbent.
	15	.094	79.56	No discomfort noted during dive. 5R - 10W
	30	.093	79.56	sequence throughout duration of dive.
	45	.024	82.60	
	1 hr.	.339	79.56	Ave. CO2 - .137
	1 " 15	.045	79.56	Ave. O2 - 80.81
	1 " 30	.113	83.65	
	1 " 45	.212	80.58	
	2 hrs.	.115	82.62	
27	0	.094	82.62	Sample after purge - same absorbent used in
	15	.409	75.49	dive No. 26. No discomfort noted during dive.
	30	.158	75.49	5R - 10W sequence throughout duration of dive.
	45	.247	75.49	
	1 hr.	.597	75.49	Ave. CO2 - .377
	1 " 15	.511	72.43	Ave. O2 - 74.80
	1 " 30	.373	74.46	Total time absorbent used - 2 hours.
	1 " 45	.505	71.38	Total gas used in 4 hours - 210.94 liters.
	2 hrs.	.501	70.37	

DATA SHEET NO. 3

DATA SHEET NO. 4

SECOND ENDURANCE RUN, LARGE PIRELLI - DEPTH 15 FEET.
PURPOSE: TO DETERMINE CANNISTER EFFICIENCY

Same CO2 Absorbent Used Throughout.

DIVE NO	SAMPLE TIME	ACTUAL CO2	EFFECTIVE CO2	ACTUAL O2	EFFECTIVE O2	REMARKS
	0	.023	.034	74.50	108.36	Sample after purge. Each diver purged lungs prior to taking 1st sample - 5 breaths used. Ave. effect CO2 Ave. effect O2 5R - 10W sequence.
	15	--		--		
28	30	.023	.034	84.82	123.37	
	45	.023	.034	84.82	123.37	
	1 hr.	.023	.034	84.82	123.37	
	Purge	.133	.194	79.56	115.72	Sample after purge. Ave. effect CO2 Ave. effect O2 5R - 10W sequence
	1 hr.15	.201	.293	83.65	121.67	
29	1 hr.30	.010	.019	83.65	121.67	
	1 hr.45	.096	.139	81.60	118.69	
	2 hrs.	.371	.539	74.74	108.71	
	Purge	.022	.031	82.66	120.23	Sample after purge Ave. effect CO2 Ave. effect O2 5R - 10W sequence.
	2 hr.15	.023	.034	79.53	115.68	
30	2 " 30	.044	.064	79.53	115.68	
	2 " 45	.023	.034	79.53	115.68	
	3 hrs.	.023	.034	82.66	120.23	
	Purge	.046	.067	81.58	118.66	Sample after Purge Ave. effect CO2 Ave. effect O2 5R - 10W Sequence.
	3 hr.15	.074	.108	83.63	121.64	
31	3 " 30	.094	.137	78.51	114.20	
	3 " 45	.226	.329	79.53	115.68	
	4 hrs.	.175	.255	77.49	112.71	

DATA SHEET NO. 4

DATA SHEET NO. 5

FINAL ENDURANCE RUN - LARGE PIRELLI - SURFACE 5R - 10 W

TIME	CO2	O2	REMARKS
Start	.020	84.64	Sample after purge - 1st diver
0-15"	.024	84.64	Dive No. 32
0-30"	.023	84.64	
0-45"	.099	84.64	
1 hr.	.024	84.64	
Purge	.675	80.53	Sample after purge - second diver
1-15	.224	84.64	Dive No. 33
1-30	.224	83.61	
1-45	.145	82.60	
2 hrs.	.144	84.62	
Purge	.093	88.72	Sample after purge - Third diver
2-15	.113	81.54	Dive No. 34
2-30	.043	85.65	
2-45	.096	83.49	
3 hrs.	.073	77.44	
Purge	.145	82.57	Sample after purge - Fourth diver
3-15	.837	80.52	Dive No. 35
3-30	.250	90.77	
3-45	.350	94.88	
4 hrs.	.330	96.93	
Purge	.957	72.31	Sample after purge - Fifth diver
4-15	.523	76.42	Dive No. 36
4-30	1.247	75.39	
4-45	1.10	75.39	
5 hrs.	1.74	73.34	
Purge	.306	90.77	Sample after purge - Sixth diver
5-15	2.768	77.44	Dive No. 37
5-25	3.876	74.36	Absorbent exhausted 50% blue

DATA SHEET NO. 5

SMALL PIRELLI - MODEL S-701 - DATA SHEET #6

Depth: Surface - Duration: 30 Minutes 5R-10W-5R-10W

Dive No	After Purge - 0 Minutes				15 Minutes				30 Minutes			
	Actual CO2	Effect CO2	Actual O2	Effect O2	Actual CO2	Effect CO2	Actual O2	Effect O2	Actual CO2	Effect CO2	Actual O2	Effect O2
1	.271	.271	75.40	75.40	.022	.022	74.36	74.36	.182	.182	71.29	71.29
2	.124	.124	82.60	82.60	.783	.783	71.35	71.35	.094	.094	71.35	71.35
3	.023	.023	80.52	80.52	.024	.024	58.98	58.98	.287	.287	64.11	64.11
4	.024	.024	81.54	81.54	.574	.574	64.11	64.11	Lost Sample			

Actual CO2			Effective CO2			Actual O2			Effective O2		
Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
.783	.022	.219	.783	.022	.219	82.60	59.98	72.33	82.60	58.98	72.33

Depth: 15 feet - Duration: 30 Minutes 5R-10W-5R-10W

Dive No.	After Purge - 0 Minutes				15 Minutes				30 Minutes			
	Actual CO2	Effect CO2	Actual O2	Effect O2	Actual CO2	Effect CO2	Actual O2	Effect O2	Actual CO2	Effect CO2	Actual O2	Effect O2
5	.046	.067	84.67	123.16	.110	.160	84.67	123.16	.609	.886	80.58	117.20
6	.022	.032	79.36	115.43	.130	.189	66.26	93.38	.212	.309	67.29	97.88
7	.020	.031	90.80	132.07	.043	.063	77.51	112.74	.094	.137	79.56	115.72
8	.023	.034	74.31	108.09	.021	.031	84.59	123.04	.040	.060	87.67	127.52

Actual CO2			Effective CO2			Actual O2			Effective O2		
Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
.609	.021	.114	.886	.031	.167	90.80	66.26	79.77	132.07	93.38	115.78

DATA SHEET NO. 7

SMALL PIRELLI - MODEL S-701

DEPTH: 30 FEET DURATION - 30 MINUTES 5R-10W-5R-10W

DIVE NO	AFTER PURGE 0 MINUTES ACTUAL CO2	EFFECT CO2	ACTUAL O2	EFFECT O2	15 MINUTES ACTUAL CO2	EFFECT CO2	ACTUAL O2	EFFECT O2	30 MINUTES ACTUAL CO2	EFFECT CO2	ACTUAL O2	EFFEC O2
9	.023	.044	74.31	141.93	.021	.040	84.59	161.57	.040	.077	87.67	167.4
10	.047	.091	85.62	163.53	.031	.059	84.59	161.57	.020	.040	79.45	151.7

ACTUAL CO2			EFFECTIVE CO2			ACTUAL O2			EFFECTIVE O2		
MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN	AVE
.047	.020	.030	.091	.040	.058	87.67	74.31	82.71	167.45	141.93	157.97

DATA SHEET NO. 8

ENTRANCE RUNS - SMALL PIRELLI - SURFACE
PURPOSE: TO DETERMINE MAXIMUM LIFE OF UNIT AND CANNISTER EFFECIENCY UNDER CONDITIONS OF MODERATE WORK. 5R - 10W

DIVE NO.	SAMPLE TIME	ACTUAL CO2	ACTUAL O2	REMARKS
11	0 min.	.023	84.62	Purge Sample
	15 min.	.031	72.31	
	30 min.	.023	74.36	
	45 min.	.043	74.36	
	60 min.	.023	74.36	
	1 hr. 15	.123	71.29	Gas Supply exhausted
12	0 min.	.021	89.73	Purge Sample
	15 min.	.060	80.48	
	30 min.	.065	81.51	
	45 min.	.021	80.48	
	60 min.	.041	76.37	
	1 hr. 15	.268	78.42	Gas Supply exhausted

DATA SHEET NO. 8

TEST OF WRIST GUAGE CALIBRATION - DATA SHEET #9(1).

INCREASING PRESSURE

Depth	10 ft.		20 ft.		30 ft.		33 ft.		40 ft.		50 ft.	
Wrist Guage No	Value in Meters	Value in Feet	Value in Meters	Value in Feet	Value in Meters	Value in Feet	Value in Meters	Value in Feet	Value in Meters	Value in Feet	Value in Meters	Value in Feet
1	2.8	9.2	6	19.7	9	29.5	10	32.8	12	39.4	15	49.2
2	2.2	7.2	5.5	18.0	8.8	28.9	10	32.8	11.8	38.7	15	49.2
3	2.5	9.2	5.2	17.1	8.2	26.9	9.5	31.2	11.2	36.7	14.6	47.9
4	3.0	9.8	6.0	19.7	8.8	28.9	10	32.8	11.2	36.7	14.2	46.6
5	2.2	7.2	5.0	16.4	8.5	27.9	9.5	31.2	11.3	37.1	14.2	46.6
6	2.7	8.9	5.8	19.0	9.1	29.9	10.1	33.2	11.3	37.1	14.3	46.9
7	2.8	9.2	5.2	17.1	8.5	27.9	9.5	31.2	11.8	38.7	15	49.2
8	0		0		0		9.5	31.2	11.8	38.7	15	49.2

DECREASING PRESSURE

1	3.2	10.5	6.5	21.3	9.7	31.8	10.3	33.8	12.2	40.0	15.8	51.8
2	2.9	9.5	6	19.7	9	29.5	10.1	33.2	12	39.4	15.2	49.9
3	4	13.1	6	19.7	9.3	30.5	10.2	33.5	12.2	40.0	15.5	50.9
4	3.6	11.8	6.1	20.0	9.2	30.2	10	32.8	12	39.4	15	49.2
5	.2	.7	1.0	3.3	4.6	15.1	5.5	18.0	8	26.2	11.2	36.7
6	3.1	10.5	6.2	20.3	9.0	29.5	10.2	33.5	13	42.7	16	52.5
7	3.8	12.5	6.6	21.7	9.0	29.5	10	32.8	13	42.7	15.5	50.9
8	3.1	10.5	6.2	20.3	9.5	31.2	10.4	34.2	12.3	40.4	15.5	50.9

Conversion factor - Meters x 3.2808 = feet.
Guage No. 5 - Glass broke - guage flooded.

TEST OF WRIST GUAGE CALIBRATION - DATA SHEET #9(2).

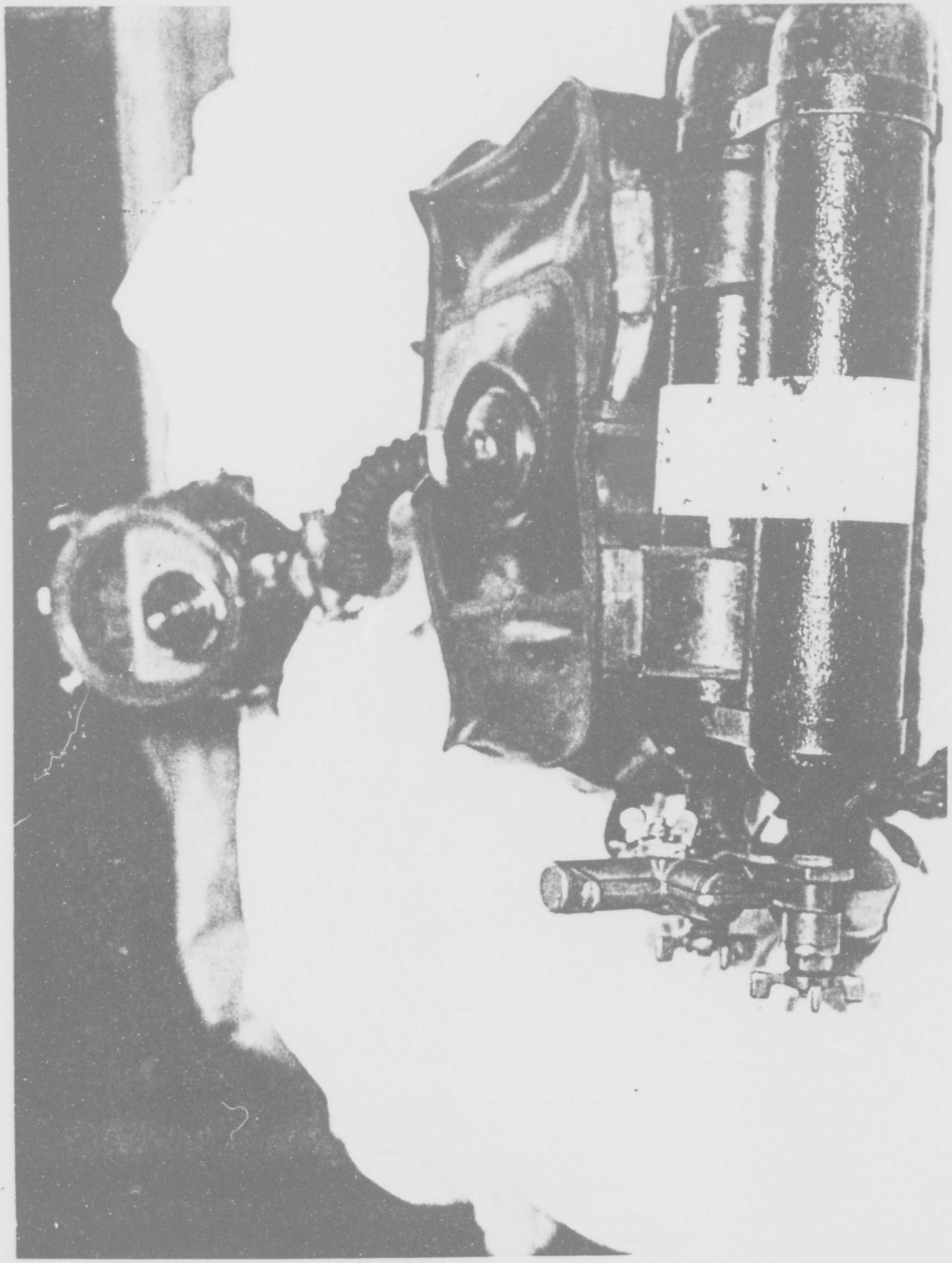
INCREASING PRESSURE

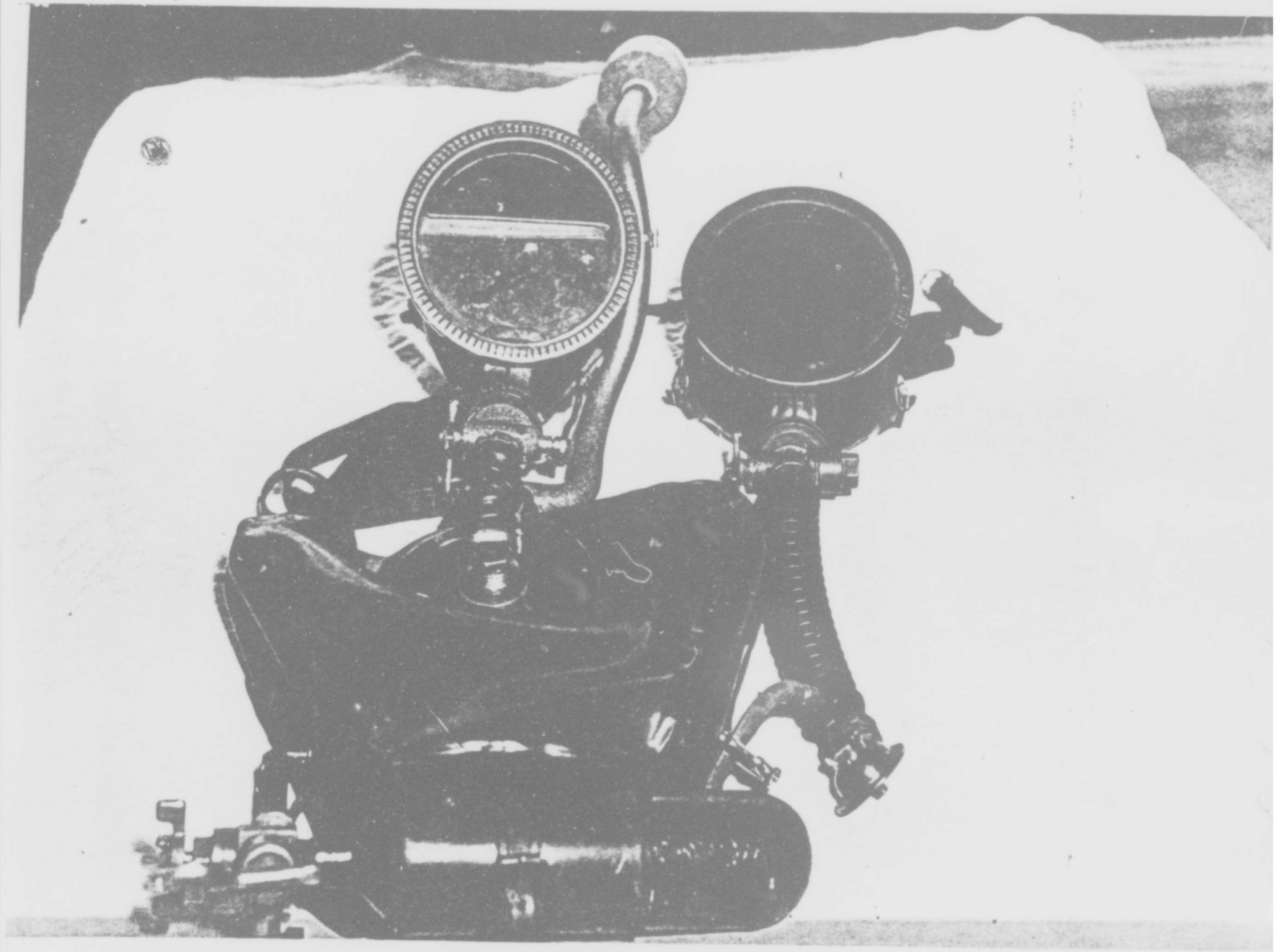
Depth	60 ft.		66 ft.		70 ft.		80 ft.		90 ft.		99 ft.	
Wrist Guage No	Value in Meters	Value in Feet	Value in Meters	Value in Feet	Value in Meters	Value in Feet	Value in Meters	Value in Feet	Value in Meters	Value in Feet	Value in Meters	Value in Feet
1	18	59.1	20.1	65.9	21.2	69.6	24.2	79.4	27.3	89.6	30.0	98.4
2	18	59.1	20	65.6	21.1	69.3	24	78.7	27.4	89.9	30	98.4
3	17.8	58.4	19.9	65.3	21	68.9	24	78.7	27.6	90.6	30	98.4
4	17.5	57.4	19.8	65.0	20.8	68.3	24	78.7	27	88.6	30	98.4
5	17.0	55.8	19.8	65.0	19.8	65.0	23.8	78.1	25.1	82.3	27	88.6
6	18.6	61.0	20.2	66.3	22	72.2	25.2	82.7	28.6	93.8	30.1	98.8
7	18.5	60.7	20.2	66.3	22	72.2	25.1	82.3	28.5	93.5	30.2	99.1
8	18	59.1	19	62.3	20.8	68.3	24	78.7	27	88.6	30	98.4

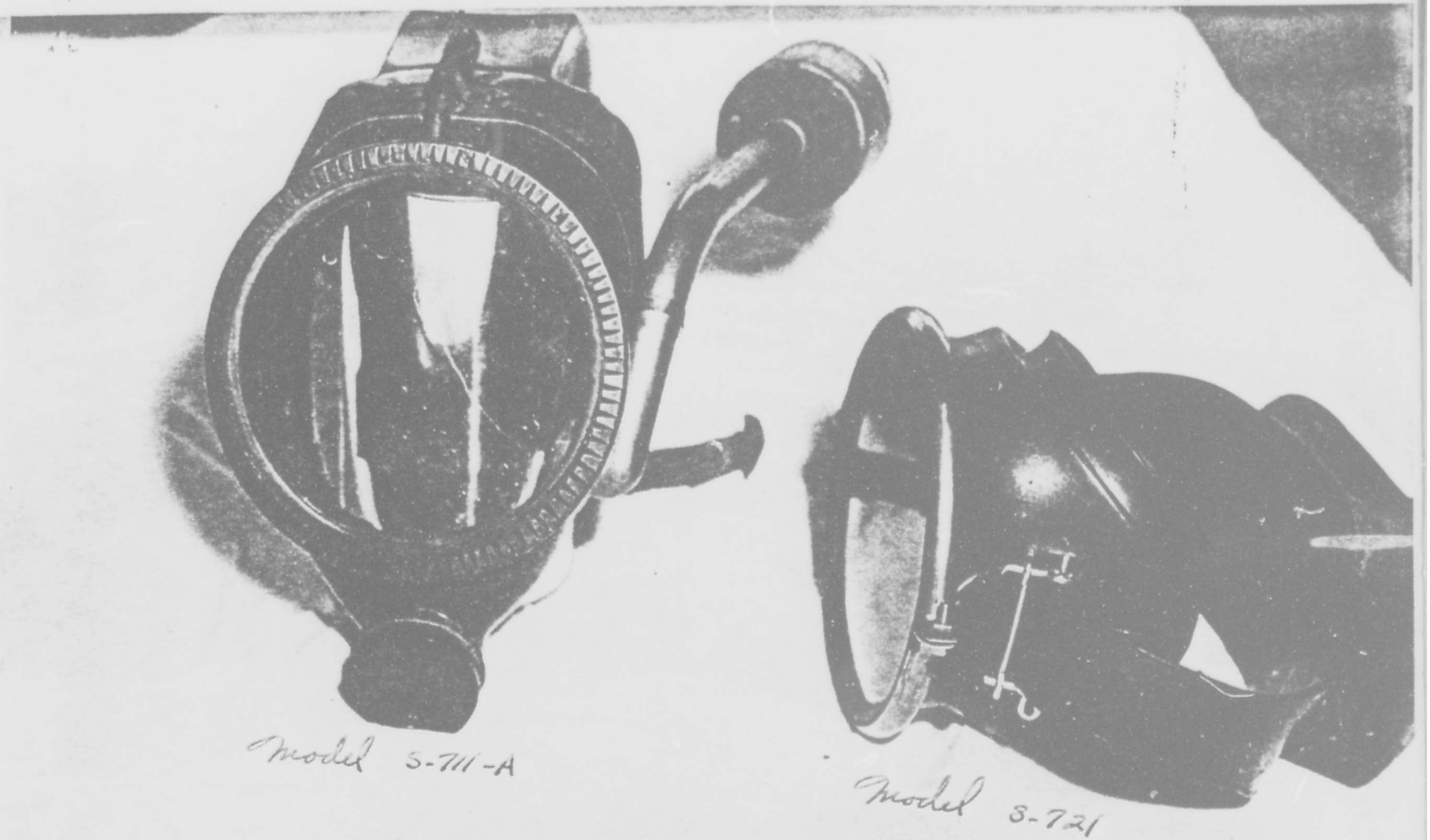
DECREASING PRESSURE

1	19	62.3	21	68.9	22.3	73.6	25.6	84.0	29	95.1		
2	18.2	59.7	20.5	67.3	21.5	70.5	24.5	80.4	27	88.6		
3	19	62.3	21	68.9	22.2	72.8	25.5	83.7	28.8	94.5		
4	18.3	60.0	20.5	67.3	21.5	70.5	24.8	81.4	28	91.9		
5	15	49.2	17	55.8	18.5	60.7	22	72.2	25.2	82.7		
6	19.3	63.3	21.5	70.5	22.5	73.8	26	85.3	29	91.5		
7	19	62.3	21	68.9	22.5	73.8	26	85.3	29	91.5		
8	18.8	61.7	20.8	68.3	22	72.2	25	82.0	28	91.9		

Conversion factor - Meters x 3.2808 = feet
Guage No. 5 - Glass broke - guage flooded.

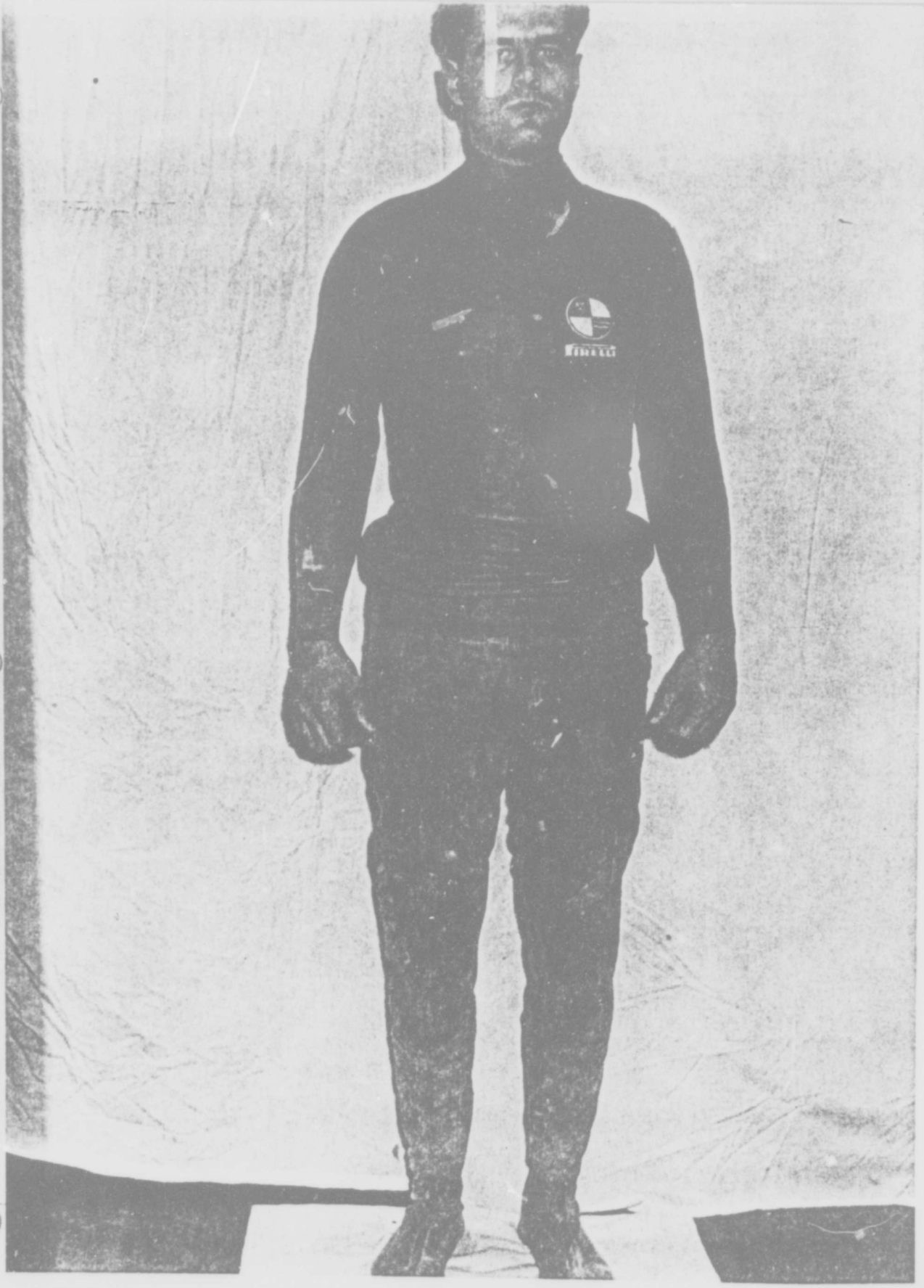






Model S-711-A

Model S-721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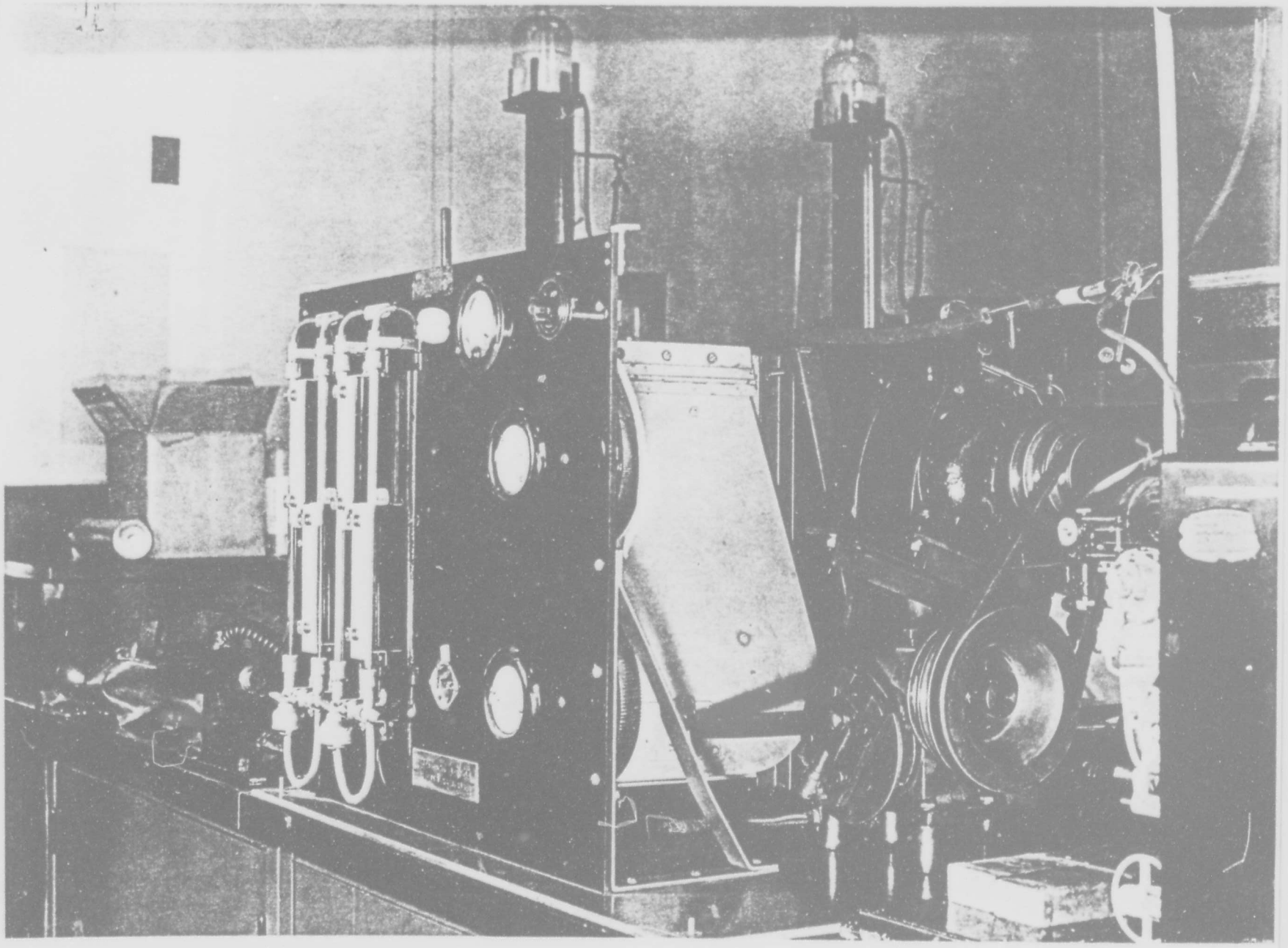

Enclosure (10)