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*SHORT COMMUNICATION*

# Submarine Escape Set Test Facilities

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**ABSTRACT**

Submarine Escape Set (SES) is used by submariners to escape from a sunken submarine. This set caters for breathing needs of the submariner under water, until he reaches the surface. Evaluation of such life-saving equipment is of paramount importance. This paper describes the submarine escape set and various constructional features and schedules of operation of test facilities designed indegenously and which can evaluate the SES. The test facility is divided into two parts: the reducer test facility, and the breathing bag test facility. The equipment has been rigorously tested and accepted by Indian Navy. Two such test facilities have been developed, one of which is installed at INS Satavahana, Visakhapatnam, and are working satisfactorily.

**Keywords:** PKY tester, KG chamber, hypoxia, depth compensator, thermal mass flow meters

## 1. INTRODUCTION

Submarine Escape set (Fig. 1) is used to save the life of submariners in the event they have to abandon the submarine and save their life. This equipment basically consists of a hydrosuit and a breathing bag. The hydrosuit protects the wearer from hypothermia[1] and reptile bites and also imparts vertical posture during ascent with the help of metal soles in the boots. It also has a facility to keep the escapee in supine position using of finger bottles provided in the thigh region. Breathing bag (Fig. 2) is an annulus rubber bag worn round the neck and connected to the hydrosuit breathing track at mouth with swivel arrangement. The breathing bag caters for the breathing needs of the submariner throughout the ascent duration. This bag is fitted with various valves like demand valve, pressure release safety valve, valve box, canister, oxygen and mixture reducers fitted on to the bottles. Breathing bag provides breathing gases of varying composition depending on the depths with the help of mixture and oxygen reducers. The set is meant for saving from depths up to 100 m. While escaping from submarine initially the mixture cylinder fitted with depth compensated reducer and the demand valve provide the requisite gas mixture for breathing on demand up to a depth of 68 m. Between 68-45 m depth oxygen cylinder fitted with hermetically-sealed reducer starts to provide oxygen at preset rates (Table 1) independent of demand up to surface. It is of paramount importance that the components should be periodically evaluated for their functional intactness without actually putting the equipment into water . The present test facilities are designed to meet the test schedules laid down for the submarine escape set.

## 2. DESCRIPTION OF SUBMARINE ESCAPE SET

Figure 3 shows the test facilities developed initially as MK I which are in use at DEBEL. Figure 4 shows the improved version of the test facilities (MK-II) which has been further modified and supplied to Navy. The concept of modularity and ease of operation are maintained in both facilities which are in working condition. The test facilities are divided into two parts reducer test facility and breathing bag test facility.


**Figure 1. Submarine escape set.**

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**Table 1. Reducer test facility test schedule (depth chart). Constant flow rate of oxygen fed by the reducer and the changeover valve at varying depths:**

(a) During descent (surrounding pressure increases)

| | | | | | |
|---|---|---|---|---|---|
| Depth of submergence (m) | 0 | 24 | 37 | 68 | 100 |
| Pressure in chamber (kg/cm$^2$) | 0 | 2.4 | 3.7 | 6.8 | 10 |
| Oxygen flow rate (l/min) | 0.3-0.6 | 0.2-0.6 | 0.5-1.1 | 0 | 0 |

(b) During ascent (surrounding pressure decreases)

| | | | | |
|---|---|---|---|---|
| Depth of submergence (m) | 68 | 45 | 20 | 0 |
| Pressure in chamber (kg/cm$^2$) | 6.8 | 4.5 | 2.0 | 0 |
| Oxygen flow rate (l/min) | 0 | 0-1.1 | 3.0-4.4 | 3.2-4.4 |

### 2.1 Reducer Test Facility

In case less oxygen is supplied to the submariner, it causes hypoxia[2] and if excess of oxygen is supplied it causes oxygen poisoning[3]. So it is essential to provide the submariners with exact rated flows of oxygen during the escape. Keeping this in mind, the reducer of the oxygen cylinder of the set has been constructed to deliver the oxygen as per the rate mentioned in Table 1. A test facility was designed to meter the correct quantity of oxygen delivered into the bag. This facility is called Reducer Test Facility. This test facility basically consists of a Pressurisation vessel, breathing bag simulator, which consists of depth compensator, air mix clipper and NRV (non-return valve). Thermal mass flow meter to meter the flows, and a digital readout connected to three pressure sensors through a selector switch. Three sensors viz., sensor 1 to view the vessel pressure, sensor 2 to view low pressure (LP) setting of the reducer, and sensor 3 to view the pressure in the depth compensator, are connected as shown in Fig 5. The source of pressurised air is from the compressor. The oxygen cylinder fitted with reducer is pressurised in the pressurization vessel up to 10 kgf/cm$^2$. The connection details of the circuit are also shown in Fig 5. The cylinder to be tested is kept inside the chamber in spindle-open condition and the chamber is pressurised gradually in steps. This is equivalent to actually testing the reducer

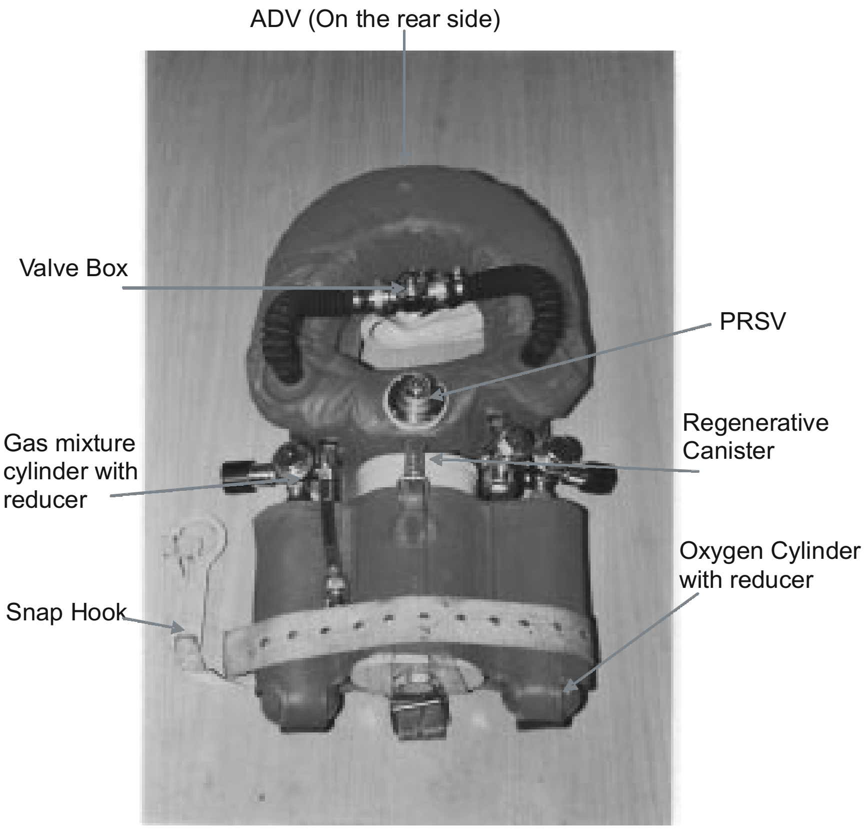


**Figure 2. Breathing apparatus.**

Figure 3. Reducer and breathing bag test facility MK-I.

at those depths inside the sea. Readings are to be noted at the specified depths as shown in Table 1.

### 2.2 Breathing Bag Test Facility

This facility is designed to test pressure release safety valve (PRSV), automatic demand valve (ADV), valve box, canister, reducer safety valves of oxygen and mixture reducers, and hydrosuit. The test facility is designed in modular concept wherein each test is performed by pre-established test circuits marked with the test name. Separate fixing adapter with swivel mechanism with shutoff valves are provided for quick connection and disconnection of test circuit. The modular concept uses separate dedicated sensor and indicators for each test which dispenses the interchange of connections and helps in easy troubleshooting and replacement of components. Turbine flow meters[4], thermal mass flow meters[5] were used in conjunction with digital pressure indicators and dial pressure gauges. Hydrosuit inflation and pressure holding test is provided with dial pressure gauge with press to measure facility to avoid eventual excess pressure being applied to the gauge. This facility can test at a time five breathing bags for various components *in situ* condition (without dismantling from the bag). This facility is very useful when large number of bags are to be tested. The accuracy of digital flow meters and pressure indicators eliminates observer errors. This facility uses compressor and dispenses the storage of big cylinders at high pressures. More than 500 sets have so far been tested on the test facility established at INS Satavahana, Visakhapatnam.

## 3. DESIGN CONSIDERATIONS

Both reducer and breathing bag test facilities are designed to be stand-alone. Single compressor drives both the facilities at a time. All test circuits are pre-laid, no interchange of connections or devices are required unlike in PKY tester or KG chamber. This drastically reduces the testing time and test preparation time. Safety valves are provided in the circuitry for pressure vessel to vent out eventual excess pressure. All circuitry materials are indigenous. Stainless Steel is chosen for pressure vessel and for all internal piping to make the system corrosion resistant. A User Handbook giving description of initial checks provided to find out the serviceability of each circuit. Digital displays add to the ease of reading. Three-position selector switch is provided for ready noting of readings and also to diagnose whether the depth compensator is functioning normally or otherwise (the readings in position 1 should be less than position 3 for flow to occur). Thermal mass flow meters known for their accuracy and repeatability have been used.

## 4. OPERATION OF TEST FACILITIES

### 4.1 Operation of Reducer Test Facility

The oxygen cylinder fitted with reducer and charged to 200 bar is connected as shown in the Fig 5. The lid

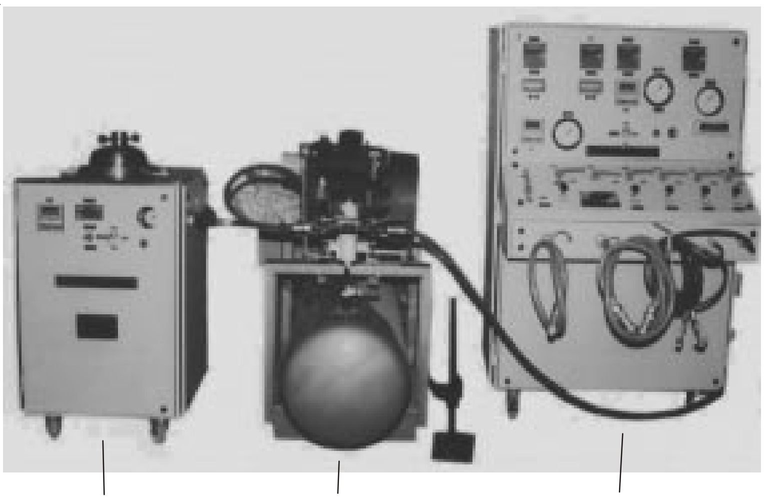


Figure 4. Reducer and breathing bag test facility MK-II.

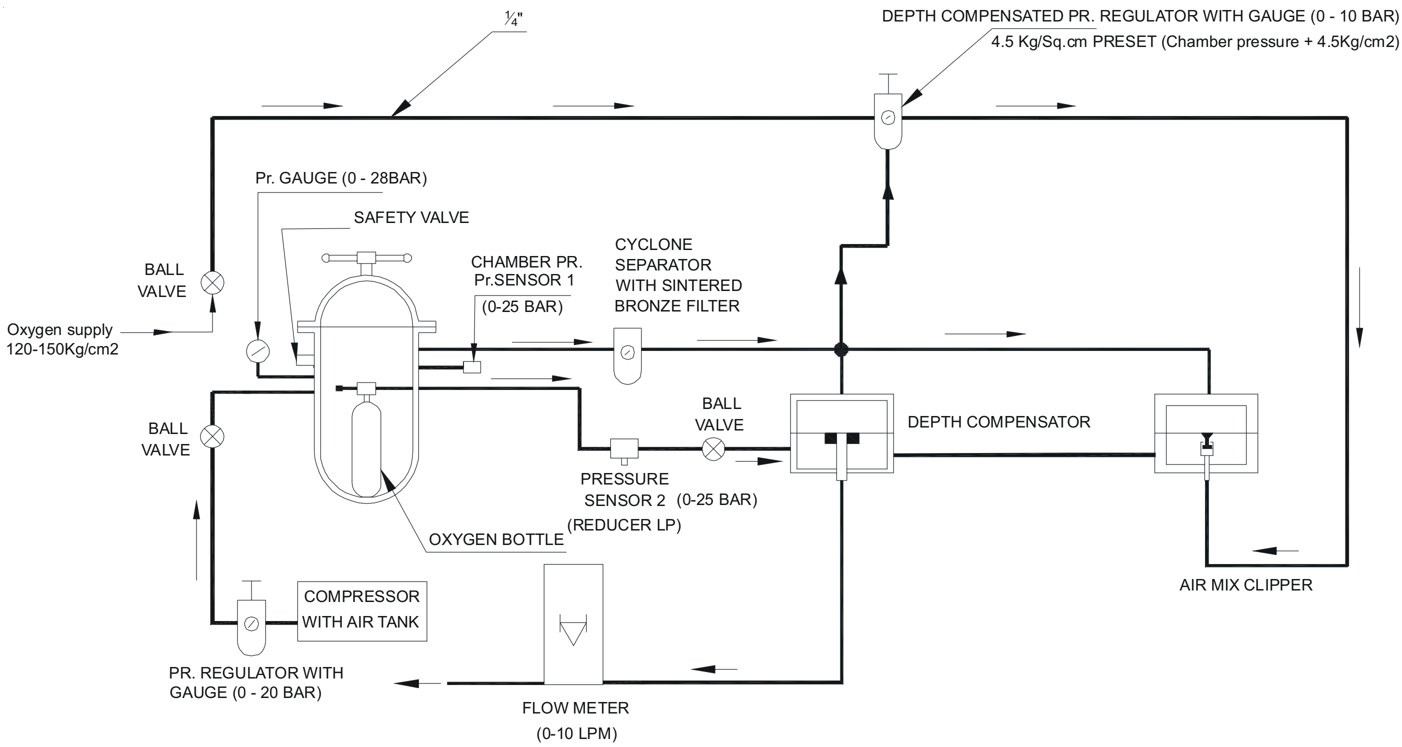


**Figure 5. Schematic layout of reducer test facility.**

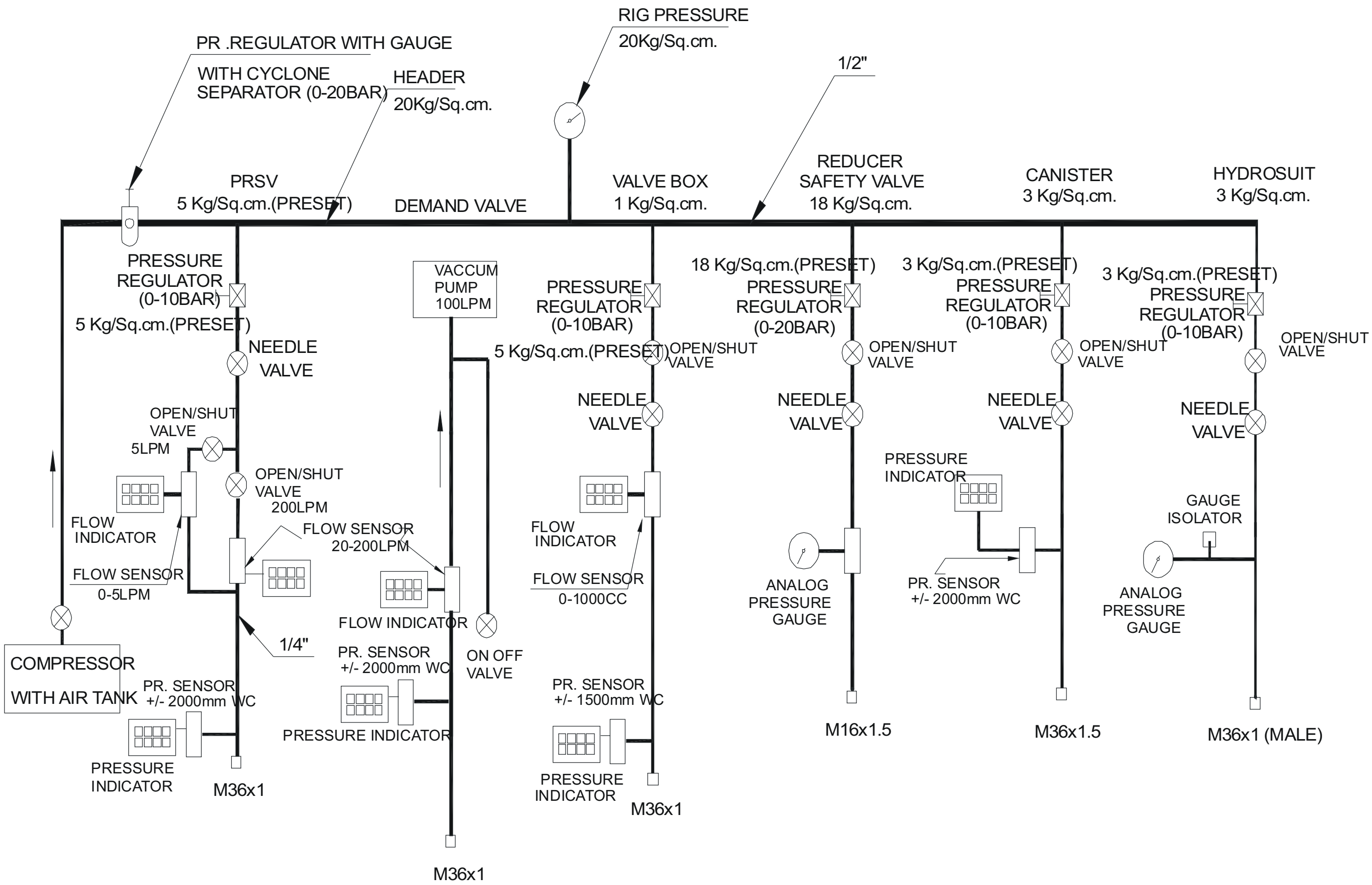


**Figure 6. Schematic of breathing test facility.**

**Table 2. Test schedule prescribed for breathing bag test facility**

| | |
|---|---|
| 1 | Resistance of breathing apparatus should be from 105 to 170 mm $H_2O$ at a suction of 50 lpm |
| 2 | Demand valve flow should be more than 40 lpm |
| 3 | Resistance of safety valve of breathing bag for a flow of 3 lpm should be from 200 to 450 mm $H_2O$ when adapter nut is screwed up completely |
| 4 | Resistance of safety valve of breathing bag for a flow of 3 lpm should be from 50 to100 mm $H_2O$ when adapter nut is unscrewed completely |
| 5 | Internal regenerative canister is considered tight if height of liquid level in manometer of 100 mm $H_2O$ and does not vary for one min. |
| 6 | No bubbles should come from the canister when dipped in water with a pressure of 1200-1300 mm $H_2O$ for external tightness. |
| 7 | Safety valve of oxygen reducer should open between 9 kg/cm$^2$ to 16 kg/cm$^2$ |
| 8 | Safety valve of mixture reducer should open between 12.5 kg/cm$^2$ to 19 kg/cm$^2$ |
| 9 | Valve box mica exhalation and inhalation valves are gas tight if the leak is below 0.55 lpm for 200 mm $H_2O$ pressure |
| 10 | Pressure at outlet should be from 5.5 to 6.5 kg/cm$^2$ for oxygen reducer and 5.3 to 6.6 kg/cm$^2$ for mixture reducer when pressure in cylinder is 180-220 kg/cm$^2$ |
| 11 | Resistance of apparatus should not exceed 25 mm $H_2O$ to a flow of 30 lpm with uncharged canister |
| 12 | Hydro suit will be inflated to a pressure of 200 mm mm $H_2O$ after tying the bib portion of the hydro suit. The hydro suit is tested for any leaks by applying soap solution on the surface. Also there should not be any pressure drop within 5 min. |

is closed and the pressurisation valve is operated slowly in steps as per the depth chart for descent. The pressurisation valve is closed and the vent valve is gradually opened to note ascent values. The readings are noted down at each depth and are compared with the admissible values.

## 4.2 Operation of Breathing Bag Test Facility

Figure 6 gives a schematic of the test facility with various preset lines like pressure-release safety valve, demand valve, valve box, canister, reducer safety valve and hydrosuit. To conduct the test, the required test line is chosen and the breathing bag is connected to the swivel connector at mouthpiece by hand, tightening the threads and the shutoff is opened to note down the readings of pressure/ flow indicator as each test line is preset for the test. The shutoff valve is closed after the test is complete and the breathing bag is disconnected from the swivel connector. Detailed procedures are given in the user handbooks available with the Navy and also at the DEBEL. The tests are simplified by providing preset parameter lines. For testing hydrosuit, the mouthpiece union is connected to

**Table 3. Reducer test facility (MK-I) performance comparison**

| Depth (Meter) | Normal value of flow (l/min) | Flow reading on certified test equipment (KG Chamber) | Flow reading on new test equipment (Reducer test facility) |
|---|---|---|---|
| 0 | 0.3-0.6 | 0.45 | 0.47 |
| 24 | 0.2-0.6 | 0.40 | 0.36 |
| 37 | 1.1-0.5 | 1.0 | 0.90 |
| 68 | 0 | 0 | 0 |
| 45 | 0-1.1 | 0.6 | 0.78 |
| 20 | 3-4.4 | 3.7 | 3.86 |
| 0 | 3.2-4.4 | 3.8 | 3.94 |

**Table 4. Reducer test facility (MK-II) performance comparison**

| Depth (m) | Normal value of flow (l/min) | Flow reading on certified test equipment (KG Chamber) | Flow reading on new test equipment (Reducer Test Facility) |
|---|---|---|---|
| 0 | 0.3-0.6 | 0.33 | 0.32 |
| 24 | 0.2-0.6 | 0.21 | 0.24 |
| 30 | 0.5-1.1 | 0.69 | 0.70 |
| 37 | 1.1-0.5 | 0.56 | 0.56 |
| 68 | 0 | 0.0 | 0.0 |
| 45 | 0-1.1 | 0.27 | 0.22 |
| 20 | 3-4.4 | 2.84 | 2.80 |
| 0 | 3.2-4.4 | 2.86 | 2.84 |

**Table 5. Breathing bag test facility (MK-I) performance comparison**

| Name of the test | Result on certified test equipment (PKYTESTER) | Result on new test equipment (Breathing bag test facility) | Normal value |
|---|---|---|---|
| Check for canister for tightness | No bubbling from canister under pressure 1200 mm $H_2O$ | No bubbling at the same pressure and there was no drop of pressure | |
| Mica inhalation valve | 0.40 LPM at 200 mm of $H_2O$ | 0.35 LPM at 200 mm of $H_2O$ | Should not exceed 0.55 LPM |
| Mica exhalation valve | 0.25 LPM at 200 mm of $H_2O$ | 0.35 LPM at 200 mm of $H_2O$ | Should not exceed 0.55 LPM |
| Safety release valve (flow 3 LPM closed position | 90 mm of $H_2O$ | 88 mm of $H_2O$ | 50-100 mm of $H_2O$ |
| Safety release valve (Flow 3 LPM) closed position | 300 mm of $H_2O$ | 238 mm of $H_2O$ | 200-450 mm of $H_2O$ |
| Automatic demand valve | Opens at suction of 145 mm of $H_2O$ | Opens at suction of 148 mm of $H_2O$ | 105-170 mm of water column |
| Flow through Automatic demand valve | 60 l/min | 88 l/min | Should be > 40 l/min |

**Table 6. Breathing bag test facility (MK-II) performance comparison**

| Name of the test | Result on certified test equipment (PKYTESTER) | Result on new test equipment (BREATHING BAG TEST FACILITY) | Normal value |
|---|---|---|---|
| Check for canister for tightness | No bubbling from canister under pressure 1200 mm $H_2O$ | No bubbling at the same pressure and there was no drop of pressure | |
| Mica inhalation Value | 0.40 LPM at 200 mm of $H_2O$ | 0.40 LPM at 200 mm of $H_2O$ | Should not exceed 0.55 LPM |
| Mica exhalation valve | 0.15 LPM at 200 mm of $H_2O$ | 0.40 LPM at 200 mm of $H_2O$ | Should not exceed 0.55 LPM |
| Safety release valve (Flow 3 LPM) open position | 80 mm of $H_2O$ | 70 mm of $H_2O$ | 50-100 mm of $H_2O$ |
| Safety release Valve(flow 3 LPM) closed position | 400 mm of $H_2O$ | 300 mm of $H_2O$ | 200-450 mm of $H_2O$ |
| Automatic demand valve | Opens at suction of 145 mm of $H_2O$ | Opens at suction of 138 mm of $H_2O$ | 105-170 mm of water column |
| Flow through Automatic demand valve | 60 l/min | 88 l/min | Should be >40 l/min |

the adaptor provided and the flutter valves and bib are tied and the head equalising valve is closed and slowly pressurised up to 200 mm water column in steps and the gauge lock switch is pressed to see the reading. This pressure should hold for 5 min without any drop. Similarly inflation compartments can also be tested.

## 5. DISCUSSION

The results obtained with standard sets brought from INS Virbahu/ Vajrabahu on KG chamber and PKY tester are in close agreement with the values obtained with reducer and breathing bag test facilities respectively and confirms the accuracy and repeatability of tests being performed (Tables 2 to 5). Also this test facility has the advantage of simultaneous testing of five breathing bags in breathing bag test facility and the time taken for each test is much less. Satisfactory certificate of performance given by Navy confirms that the utility and design meet the stated objectives.

## 6. CONCLUSION

The test facilities developed are under continuous use for the last three years. One equipment stationed at INS *Satavahana* confirms the utility and design soundness. These are steps towards indigenous development of facilities for critical Naval requirements.

## ACKNOWLEDGEMENTS

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