N.D.R.C., Division B, November 5,194

MONTHLY REPORT

Physical-Chemical and Chemical Engineering Problems
Summary of Progress September 15 to October 15, 1942.

Subsection B-7-b: Oxygen Problems - E. P. Stevenson, Chairman

SALCOMINE

Problem NL-B-42: Development of Chemicals and Apparatus for Regenerative Production of Oxygen.

Problem AC-12: Manufacture of Oxygen while in Flight for Use of the Combat Crew.

Problem NA-111: Portable Unit for Supplying Oxygen.

Problem NS-116: Portable Unit for Producing Oxygen for Welding and Cutting, and for Breathing Oxygen Aboard Aircraft.

Problem NS-117: Oxygen Producing Apparatus for Repair Ship Installation.

Problem CE-29: Field Generation of Oxygen Gas

Progress Report: Serial No. 365, September 17, 1942, "Report on Chelate Oxygen Compounds and Equipment for their Use", by Melvin Calvin.

The following reports are being prepared for formal release: "Chelate Oxygen Compounds and the Mechanism of Absorption Reactions" covering the period August 1 to September 1, by Melvin Calvin: "Development of Oxygen Carrying Chemicals", April 15 to September 1, by Harvey Diehl.

Preparation and Equivalents

Considerable effort has been directed towards the preparation of 3-ethyl salicylaldehyde. In view of encouraging reports of preliminary tests on Co-4-hydroxy-6-methyl salicylpropylenetriamine, some samples of which show an activity of 7.3%, it has become a matter of interest to consider other salicylaldehydes of this general structure.

Of a number of new chelate compounds which have been prepared recently only two show sufficient absorption of oxygen to be interesting. These are Co-3-methyl-6-chloro-salicyl-propylenetriamine, a red crystaline matter which loses one molecule of water on heating and absorption about 3% by weight of oxygen at an oxygen pressure of 150 p.s.i.; Cobalt Co-3-ethoxy-salicyl-propylenetriamine, brown-yellow crystals, absorption about 2% by weight of oxygen at an oxygen pressure of 150 p.s.i.

General methods for the synthesis of metal chelates have been studied with a view not only to produce a chemical species but also to precipitate the material in the correct crystal structure to give a maximum of activity towards oxygen. The following trial methods of preparation have been used experimentally: (1) The reagents and intermediates are reacted in a water solution and a study is made of the order of adding the reagents, (2) certain of the chelates, in particular the parent compound, form pyridine solvates which can be desolvated to highly active compounds, (3) the simple preparation may be carried out in alcohol or water-alcohol mixtures. After the new molecular species has been obtained, the problem then becomes one of testing various crystal forms, including an activation treatment consisting of heating the compound to temperatures ranging from 100-170°C. If the compound treated is not active at this stage of treatment, it is crystalized from a variety of solvents and desolvated at a variety of temperatures. A further test for activity would be a study of the oxygen absorption of solutions of the metal chelates; so far very little attention has been paid to this last method.

The density of the parent compound has been determined by both gas and liquid displacement methods, and while there is not exact agreement since the two methods actually measure different things, it would seem that there is at least a small decrease in density during oxygenation indicating an expansion of the crystal lattice. The inactive form is considerably more dense than either the active or the peroxide.

A schedule is now in operation whereby three men are producing about 575 lbs. of Salcomine granules in a 40-hour week. This production is probably ample for our present experimental program and gives some indication as to what might be done on large scale production.

A careful study was made of the raw materials used in the preparation of Salcomine to find the reason for some non-uniformity in the oxygen capacity of the material produced on a large scale. This was traced to non-uniformity and impurities in the diamine, the other components being standard.

A sample of Salcomine was tested for its dust explosion hazard and found to be equivalent or a little worse than corn starch which is considered a serious hazard in industry.

The magnetic susceptibility of Co-3-methylsalicyl-propylenetriamine has been measured as a function of oxygen uptake at room temperature, and the value observed to correspond to three unpaired electrons before oxygenation and two unpaired electrons at a usual one to one absorption. The exact values of susceptibilities at intermediate points of oxygenation are somewhat uncertain.

The heat of oxygenation of Co-3-methoxy-salcomine has recently been determined at 20.8 Calories per mole, this value agreeing quite well with the value 20.4 Cals. per mole previously obtained. Other heats of oxygenation are: Salcomine, 19,600 Cals.; 3 ethoxy Salcomine, 18,900 Cals.; 3 nitro Salcomine, 17,300 Cals.

Measurements of thermal conductivity and rates of oxygen absorption and desorption were made on cakes and granules of Salcomine containing up to 10% of aluminum flakes, bronze flakes and copper powder; very little, if any, effect of the metals was observed.

Recent efforts on behalf of the preparation of di(2-hydroxy-3-ethoxybenzal)ethylenediimine cobalt —(Co-OxBT) — have centered around the preparation of 2-hydroxy-3-ethoxybenzaldehyde, the intermediate, a suitable commercial source for which has not yet been found. The Reimer-Tiemann reaction on O-ethoxyphenol is being studied with a view to preparing this intermediate on a large scale. The maximum yield of aldehyde obtained so far is about 10%, the amount of unreacted phenol recovered being about 50% under the most favorable laboratory conditions.

This ethoxy derivative of Salcomine having a capacity of 3.6-3.7% oxygen has been prepared in yields of better than 90% from the commercial source of the aldehyde referred to above.

No active crystals have been discovered in the material obtained by subliming the parent compound.

The X-ray study of the parent compound is progressing at present along two lines based upon two series of photographs. One has to do with the possible appearance of additional lines upon cycling. The second is a series of samples of different oxygen content to determine at what critical composition transition takes place from the oxygen-free type of structure to the oxygenated type. Neither of these sets has progressed far enough to warrant detailed description.

Additional studies on the decomposition of the photo-oxide of 9,10,diphenylanthracine in various solvents have been carried out and the results show that smooth and rapid deoxygenation can be obtained by heating at temperatures as low as 150°C. The nature of the solvent as well as its boiling point affect the extent of deoxygenation as well as the deterioration of the hydrocarbon formed. Experiments so far have been designed to show relative rates of photooxidation and give no information as to whether a practical cyclic system may be operated.

Rates of Reaction and Life Tests

It is believed that very considerable progress is now being made towards determining the cause and deterioration in oxygen capacity of the parent compound. It has been observed that the rate of deterioration is definitely a function of degree of saturation of the compound. This has been observed both with a dry bed of the material subjected to cycling tests and in oil suspensions of the parent compound also subjected to cycling operations. It is believed that when the absorption phase of the cycle introduces sufficient oxygen into the molecule to represent a high degree of saturation that the rate of deterioration is materially greater than when the amount of oxygen introduced is only a small fraction of the saturation value. Although no accurate data are available at present, there is some indication that operations based upon 60% saturation per cycle results in a deterioration of 10 - 20% of the capacity per 100 cycles, whereas saturation to 40% results in a deterioration rate of 2% or less per 100 cycles. This is further borne out by a rapid decrease in capacity as the cycling operations are continued which would indicate that the defect is based upon the existing saturation at any point and that as the process procedes the degree of saturation determined by the method of operating becomes an increasing proportion of the total saturation which decreases as deterioration procedes. As an example it has been observed that a unit operated at a high rate of absorption will give a fair yield of oxygen over 100-150 cycles, and then deteriorate so rapidly that production practically ceases in a few more cycles.

The above observations and explanation would indicate that further consideration of the chemical system might tend very definitely towards lower degrees of saturation, which in turn would be reflected in larger equipment. Inasmuch as some of the observations made in the past, for example, a higher rate of deterioration at high absorption pressures, may be traced directly to degrees of saturation, and should now be re-examined for modifications which may retain some of the advantages originally attributed to the proposed systems, and so adjusted to avoid the difficulty of high rates of deterioration. Among these might be considered the so-called adiabatic cycle in which absorption and desorption were controlled through variations in pressure and consistent temperature, such a system being dependent upon high absorption pressures.

An analytical study is being made of white oil suspensions of the parent Salcomine with samples representing the original compound, a compound ground in a ball mill, and the compound ground in the ball mill and subjected to cyclic oxygen absorption and desorption; the capacity has fallen to approximately 1/4 of its original value. The last named sample would seem to represent another sample of material whose deterioration (in capacity) is not matched by loss of recoverable aldehyde. The deteriorated compound was found to be slightly rejuvenated upon heating for a number of hours at 170°C. The extent of reaction was so small, however, that the treatment does not seem to be practical for recovery of spent material.

When moist air is used to oxygenate Co-Ox-BT-((di(2-hydroxy-3-ethoxybenzal)ethylenediimine cobalt))- and the material cycled continuously in the manner in which it would be used employing oxygenation temperatures of 20° and deoxygenation temperatures of 120°, a more or less consistent amount of water is absorbed for a given air humidity, and the oxygen carrying capacity of the material is appreciably decreased in the higher humidity, but in each case assumes a definite value which is a function of the humidity. This is using air having a humidity of 47% where 3% of water is maintained in the compound by the material continuously and carrying reversibly about 2% of oxygen.

A considerable amount of work has been done on reaction rates and equilibrium pressure on those compounds which absorb oxygen at high pressures only; in particular the compound Co-3-methylsalicyl-propylenetriamine has been studied in some detail. Individual preparations seem to vary in activity and absorption rate, and considerable deterioration takes place upon cycling. The equilibrium pressures both at 0°C. and 20°C. are still uncertain, although there is evidence that at 0°C. the rate of oxygenation increases with pressure.

A series of tests have been made of the effect of water both cold and hot on the rate of deterioration of Salcomine. Salcomine soaked in cold water for a period of 15 days had its capacity for oxygen absorption reduced from 4.53% to 4.18%. Hot water causes the oxidized, or rather the material which has been deoxidized in the presence of water, to deteriorate much more rapidly. Treatment with steam is also much more destructive to the oxidized form than to the unoxidized form. Apparently the presence of hot water or steam has a serious effect on the oxygen carrying capacity of Salcomine. Further work is under way to investigate the effect of oxygenation of slurries of Salcomine at different temperatures and also to test the effect of hydrogen peroxide and formaldehyde on aqueous suspensions of Salcomine.

Toxicity Tests

Nothing to report.

Experimental Oxygen Producing Units

(1) Oil Suspensions

Two runs were made during the past month each with a fresh charge of Salcomine oil suspension. One run was made at absorption pressure of 150 p.s.i. gauge in stirred autoclave. The other run was made at a pressure of 450 p.s.i. gauge in a 10" I.D. by 7' high tower absorbent of 20 gallons capacity employing co-current up-flow of air and suspension. Initially the tower was operated without baffles, but later, because of the poor results obtained, the tower was packed with 140 horizontal baffles spaced vertically ½" apart. The desorber cools pump and compressor air, the same as used in previous tests.

Operation of the stirred autoclave at 150 p.s.i. pressure and at several inlet air rates and suspension rates confirmed the correlation obtained last month, viz, that the oxygen production per pound of Salcomine circulated is a unique function of the inlet air rate to liquid circulation rate. Tests of the co-current tower show that the baffle tower is only about half as efficient as the stirred autoclave at the same pressure at 450 p.s.i. gauge, however, the tower has approximately the same efficiency as the autoclave at 150 p.s.i. Also the time of gas contact in an open unbaffled tower is too short to obtain a reasonable production period. The baffles increase the length of the gas path through the suspension from 6 feet to about 115 feet, and more than double the production. The addition of the coil of 115 feet of $\frac{1}{2}$" pipe preceding and in series with the tower results in an additional increment of production. These observations indicate that with absorption at high pressure a single co-current tubular absorber operating at high velocity and in turbulent flow would be practical.

Unfortunately all of the runs on oil suspension were made at high degrees of saturation of the Salcomine so that the rate of deterioration in capacity was high. As is now realized, the degree of saturation must be kept in some reduced value in order to extend the life of the Salcomine to a practical point.

(2) <u>Circulating Solid</u>

The N.D.R.C. has now assumed the responsibility of further development of oxygen producing equipment which was originally designed and built for the Naval Research Laboratory. This unit differs somewhat from those previously described in having a mass of the powered absorbent moved by means of screw conveyors through stages of absorption and desorption. The absorbent chemical in this case is the methoxy derivative of Salcomine. The absorption and desorption chambers are large diameter pipes tilted somewhat from the horizontal and the powered material which fills about 1/3 of the pipe is moved constantly up hill by means of screw conveyors. The absorption chamber is cooled, but the desorption chamber is heated. A back pressure of oxygen is maintained on the cells between the two chambers to prevent contamination of the product with air. There has been a considerable problem in heat transfer to the absorbent material, and as this is being solved the rate of oxygen production has increased from about 12 cu. ft. per hour in the initial tests to over 90 CFH. This type of unit has some advantages over the stationary bed type principally relating to continued operation rather than by the batch process, and it is felt that valuable contributions to the problems of oxygen production may be made along these lines. It is also proposed some elements of this system may be combined with the "fluidized" system described below.

(3) Fluidized System

An examination of the so-called "fluidized" system is being again taken up. It will be remembered that some work was done about a year ago on this method, and that the program was abandoned because of the then-known characteristics of the material Salcomine. The properties of the newer derivatives of Salcomine, especially the methoxy compound, make the fluidized system seem attractive. In this system the absorbent material in finely purified form is suspended in the current of gas and caused to circulate in this gaseous stream from one stage of operation to the next in the cycle. This has the double advantage of giving continuous operation and also heat transfer through the gas medium. Preliminary experiments on a larger scale have involved absorption and desorption studies on approximately 20 gms. samples of the methoxy compound in a tube 22 mm. in diameter and 50 cm. long, jacketed with a heat transfer fluid that can be either heated or cooled. The initial tests were made with no net flow of the solid such as would take place in a continuous unit, and, therefore, the data approximates that which would be obtained in the stationary bed reactors. The dusting of the compound appeared to be greatest in the initial operation and to become progressively low, which would indicate that it was due to the dusting in the original material and probably not to attrition during the fluidized operation. The rate of absorption is very high for the first five minutes and then tapers off asymptotically. The particular material used in these tests did not have a high saturation value and it is believed that more favorable results might be obtained with more reactive materials. The rate of absorption at $0^{o}C.$ was very close to that at $-12^{o}C.$ but there was considerable decrease in rate of absorption at $+7^{o}C.$

Field Oxygen Producing Units

The tests upon the 300 CFH unit at the Engineering Experimental Station at Annapolis are continuing satisfactorily. The rate of oxygen production has now been increased to something over the rated capacity of the unit. A maximum production of 325 CFH has been obtained and production standardized at about

305 CFH. Earlier tests on this unit did not approach this production.

Progress on the 600 CFH shipboard unit has been hampered by lack of shop facilities and poor workmanship. Improved inspection facilities are now available and it is hoped that the quality of the work will be satisfactory. The first two reactors of four have been completed, although they have not yet been satisfactorily pressure tested. Some reworking will be necessary but it is hoped that these two reactors will be ready for filling in a week or two. Not all of the supplies have been obtained for the last two reactors, and fabrication of these units is, therefore, held up. Other equipment including drying equipment is now available.

The two portable chemical units it is now believed will be ready sometime in December. Both the reactor and compressor trailer layouts are being worked on, and the piping layout for the reactor trailer is practically complete. However, difficulty is being experienced in securing the necessary trailers for mounting these units.

Calculations and flowsheets have been completed on a package reactor Salcomine unit to be transported on a plane. The thought behind this design was to minimize the amount of field erection required. The package unit would contain two reactors, two blowers, and a refrigeration heating and cooling system and timer. A number of reactor packages would be hooked up in parallel to the air and oxygen dryers and air and oxygen compressors to form a single unit of any desired capacity. Although the package itself, as now laid out, meets the space requirement for an air-transported package with standard available equipment, it is a great deal heavier than the minimum weight specified for such a package. By the use of special light-weight equipment which might be found or developed, it might be possible to cut down the excessive weight. The system utilizes gas recirculation for both heating and cooling. This results in decreasing the size of the equipment, although it increases the power consumption. However, it was thought that the unit size was of greater importance. No further work is being done along these lines, as we are awaiting engineering data on the 3-methoxy compound which appears to be a great deal more promising.

The oxygen producing unit utilizing the methoxy derivative of Salcomine at low temperatures for mounting on board bombers has now been delivered to Wright

Field and is being tested there in a specially constructed low temperature laboratory.

OXYGEN PRODUCTION BY MECHANICAL METHODS

Problem No. AC-12:	The Manufacture of Oxygen while in Flight for Use of a Combat Crew.
Problem NA-111:	Portable Unit for Supplying Oxygen.
Problem NS-115:	The Development of Equipment for the Production of Liquid Oxygen aboard a Submarine.
Problem NS-116:	Portable Unit for Producing Oxygen for Welding and Cutting, and for Breathing Oxygen Aboard Aircraft.
Problem CE-29:	Field Generation of Oxygen Gas.
Progress Report:	"Preliminary Results of Tests on Regenerators", by B. F. Dodge, August 1, 1942, being prepared for formal release.
Progress Report:	"Rectification of Air in a 2-inch Packed Column", by B. F. Dodge, being prepared for formal release.

Apparatus Study

The tests on the 7" regenerators with aluminum packing have been completed. The results have been analyzed and it was found as expected that in highly saturated air, temperature has a very great deleterious effect on regenerative performance. The equipment has now been dismantled and the regenerators filled with smaller crimp, more compact steel packing. It is hoped that some additional essential data may be soon available for the proper design of regenerators for some of the large scale units.

Tests of packed rectification columns are continuing and it is hoped that further information will indicate that the columns designed for the mechanical low pressure truck unit will produce oxygen of the quantity and purity calculated, although at the moment the indications are that it will fall somewhat short of this production. In view of these results, some attention is being given to the design of a tray column for this unit, and several types of bubble caps are being examined. One of the types of columns considered is that of the Aluminum Plant and Vessel Company of England, which comprises a series of bubble plants alternating with perforated plants for which greater capacity and considerably better performance is claimed.

Tests were run on a small column backed with brass shoe eyelets. These gave an H.E.T.P. about 1/3 greater than glass rings or Berl saddles, but had a considerably lower heat capacity. The advantage in lower starting time (because of reduced heat capacity) may out-weigh the disadvantage of a longer column.

Further tests on the rotating column rectifier have been conducted and a new form of rotating column is under test. The preliminary results obtained with the new column are promising.

Oxygen Producing Units

The difficulty in securing material for the trailer mounted mechanical units will undoubtedly delay the completion of these units until some time in November. A great deal of difficulty is met in trying to obtain the tubing and return bends for the high pressure oxygen after-cooler. The fabrication of such tubing seems to be new to the Aerofin Company handling the job and some development work is necessary to perfect the technique.

A new model of 1000 CFH portable truck mounted oxygen unit is being designed. It is hoped that from the early work on the first two truck units and additional information which has since been obtained, particularly in view of the pressure obtained by Professor Collins on his small unit, described below, it will be possible to build an improved unit using this capacity on a single 12' trailer. In such a unit it will probably be necessary to eliminate most of the test instruments and safety factors which will be incorporated in the first unit. In order to keep the size down to a minimum, it may be desirable to cut the flexibility of the unit somewhat, that is lower the severe operating conditions under which it might have to work, namely, 120°F. ambient air with the dew point of 195°F.

Design and testing of a trailer mounted oxygen unit producing 99.5% liquid oxygen equivalent to 100 CFH of gas is progressing. Considerable difficulty is had in obtaining deliveries on the needed equipment, most of this equipment being promised for deliveries sometime between now and January 1st. So far it has not been possible to obtain the promise of a suitable gasoline engine for powering the unit. Provided the delivery promises on the equipment are made good, it is very likely that the completed unit can be assembled for testing by March 1, 1943. The best present estimate of weight is that the unit will weigh less than 10,000 lbs. and the trailer about 5,000 lbs. This unit will operate at approximately 2500 p.s.i. air with an auxiliary ethane and butane refrigeration cycle. Experiments are under way to develop a liquid vaporizer for charging cylinders at 2000 p.s.i. and it is believed that this equipment will function satisfactorily in place of the usual oxygen gas compressor.

Design and lay-out drawings for the two submarine pilot plants is proceding satisfactorily. The regenerator sizes have not yet been set as it is still hoped to obtain information from the test work on regenerators which will permit somewhat smaller size for these units.

Approximate sizes and weights of all the equipment on both the low pressure and intermediate pressure systems of a full scale submarine plants are being obtained for submission to the Navy to permit them to compare the relative merits of an oxygen producing plant and a large liquid oxygen storage system. On the low pressure unit the regenerator sizes are being estimated as closely as possible with the information at hand.

Progress in the construction of the submarine air conditioning unit adapted for use with the standard 3000 p.s.i. compressor is satisfactory. Two automatic expansion valves are being prepared for trial on the unit at the Naval Research Laboratory, and a design has been drawn in other respects in a way to permit the carrying out of comprehensive tests for securing engineering information which does not appear to be available. The unit is designed, of course, for actual submarine operation with and without precooling of the compressed air.

All work on the column for the 400 CFH trailer mounted unit has been completed. The trailer will be delivered about October 5 and the compressor about October 25. Practically all the remaining material is on hand and it is hoped that final assembly will be completed shortly.

Some design calculations have been made on an air transported low pressure mechanical unit. This unit is being figured both with a single air feed system as on the Collins unit as well as with a double feed system. In both cases consideration is given to the use of the Collins exchangers as well as regenerators. The most difficult part in the design of this unit is the column. It is hoped that the use of multiple packed tubes will permit an efficient column of small overall height.

The reconscructed Mond unit (high pressure unit to produce 100 CFH oxygen) together with auxiliary apparatus for operation with the Ricardo compressor is now on test at Wright Field. The Ricardo compressor has just been received and will be available for testing with this unit.

A new high pressure bomber unit has been designed and the parts are about to be constructed. This unit is being designed for actual installation and trial on aircraft using the Ricardo compressor. It will be provided with automatic means for preventing disturbance of the rectifying regime during variation in altitude.

The small low pressure oxygen unit designed and built by Professor Collins has performed very satisfactorily on tests producing approximately 200 CFH oxygen of 90½% purity, with somewhat lower production for higher degrees of purity. This unit, comprising small expansion engine, rectification column and heat exchangers, is very compact and weighs 320 lbs. It is estimated that a combination air compressor and engine can be obtained weighing around 250 lbs. giving a completely selfcontained unit, except for fuel, weighing between 500 and 600 lbs. Further testing and development of this unit is being carried on at the Frigidaire Company with a view to getting into production with such units at the earliest possible date. It is expected that the unit will be slightly modified to produce around 100 CFH with a consequent saving in weight and thereby meeting the requirements of oxygen production on bombers. Another modification will lead to a unit producing around 500 CFH, thus fulfilling requirements for an easily transportable field unit.

ENGINES AND COMPRESSORS

Problem Nos.: NL-B-42; AC-12; NA-111; NS-115; NS-116; NS-117.

The first of three compressors for the low pressure 1000 CFH oxygen plants has been assembled and run a number of hours on test. Some changes appear necessary in the valve design, design of the cross head and the oil scraper rings on the piston-rod packing. It is expected that these changes can be made in two or three weeks and the compressor units made available for use on the low pressure mechanical trailer mounted units and the two chemical trailer mounted units.

The 3000 p.s.i. compressors for the high pressure trailer mounted mechanical unit and for the liquid oxygen producing unit are well under way, and it is still hoped that the first of these two units will be completed about November 1st.

The first of the small 150 p.s.i. engine compressor combinations will be delivered to Wright Field for testing with the Collins low pressure unit described above. This machine will be completed with sub-base, six volt battery, and starting equipment. The unit will also have some form of air intercooling and aftercooling built into the machine. It is hoped that the unit will be ready for testing by November 1st.

The compressor for the high pressure submarine pilot plant (600 p.s.i.) will soon be detailed and construction of the parts will be started. It is hoped that the unit will be ready for testing by the middle of January.

The compressor for the low pressure submarine pilot plant has been designed and actual construction will go forward in a short time.

The 200 CFM rotary air compressor will be ready for testing by November 15, it is estimated.

Efforts are still being made to assemble all of the material required for the high pressure oxygen compressor. The major parts of the first two stages are already assembled, and hence the low pressure oxygen compressor comprising these first two stages should be ready for testing within ten days.

The parts of the 1700 CFH low temperature expander have been finished and a preliminary test run on the oil seal and bearing assembly by operating the shaft with a steel disc instead of the turbine wheel. The shaft is of stainless steel and trouble was encountered here which was corrected temporarily by placing a carbon steel jacket over the part not subject to low temperature. One of the turbine wheels is being overspeeded to destruction. If it falls below expectations another wheel of stronger alloys is available. The expander loading mechanism consists of two 5 H.P. d.c. generators each belted to the expander with special canvas belts.

The first of the Collins type expanders has been set up in Yale laboratories for testing and in connection with the low temperature work there. This expander is being tested in connection with the switch expanders for purifying the air. The efficiency of this unit is estimated at about 80% based on enthalpy drop. A second unit now on test for some reason does not perform as well as the first unit, and is being investigated. A third expander will be completed within a week.

The high level reciprocating expander for the high pressure submarine pilot plant has been designed and detailing is under way. It is expected that the machine will be ready at about the same time as the high pressure compressor. It has been designed to utilize a hydraulic brake to absorb the work of the expansion of this unit.

The low level expander has been dormant in the past month pending the accumulation of data on the preliminary tests of the first two Collins type expanders. It is expected that this expander will be ready for operation in January.

UNDERWATER PROPULSION

Problem No. NL-B-6:- Operations of Diesel Engines on Recycled Fuel and Exhaust Gases.

The recent decision of the Bureau of Ships as ruled out the use of Diesel engines for submerged propulsion of submarines. Upon this basis the program on operation of Diesel engines with recycled fuel and exhaust gases in summarily dropped. Some thought is being given to substitution of a program on operation of gas turbines and steam turbines on recycled exhaust gases and fuel, but details of such a program have not as yet been worked out.

The program on dispersion of exhaust gases in sea water is felt to be at least as fully advanced as the operation of power plants under submerged conditions, and it is planned to hold in abeyance further work on dispersion of exhaust gases for the time being.

MISCELLANEOUS

Problem NLB-1 (Item f): Development of an Instrument for the Measurement of Oxygen Partial Pressures

Problem NA-106: Development of Oxygen Breathing Equipment and Associated Apparatus

(Item 1): Development of Oxygen Breathing Apparatus for use with Liquid Oxygen.

(Item 4): Development of Means for Automatically Eliminating Nitrogen in Oxygen Rebreathing Equipment.

Problem AC-32: Development of Pipe Thread Sealing Compounds.

(No reports to be reported)

During the month preliminary work has been carried out on the adaptation of the oxygen meter on airplanes and lighter than air craft. In addition some preliminary work on another device for conveniently detecting dangerous concentrations of oxygen and hydrogen has been under way. This device comprises a means of measuring a change in the density of the hydrogen upon contamination with oxygen, and for this purpose a change in the pitch of a whistle is suggested.

It is hoped that instruments for the conversion of liquid oxygen to gaseous oxygen at constant pressure upon demand will be ready for testing within the next few weeks. This equipment is designed to supply gaseous oxygen upon airplanes.

A survey is being made of the production of oxygen from non-regenerative chemicals such as potassium chlorate, sodium peroxide, potassium peroxide, etc., and the possibility of developing generators for handling these materials in the field. This study is directed primarily to supplying a source of oxygen for field medical use in the absence of a sufficient supply of steel cylinders for compressed gas and pending the development and production of suitable equipment for separating atmospheric oxygen.

A survey is being made of the electrolytic production of oxygen (and hydrogen) from water in portable units. A light weight cell weighing in the neighborhood of 4000 to 5000 pounds producing 1000 CFH of oxygen has recently come to our attention, and the field of low voltage high amperage electrical equipment is being canvassed for equipment for a field unit.

No progress has been made upon the development of a means for automatically eliminating nitrogen in oxygen breathing equipment.