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OAK RIDGE NATIONAL LABORATORY

Operated By
UNION CARBIDE NUCLEAR COMPANY

UCC

POST OFFICE BOX P
OAK RIDGE, TENNESSEE

CF-56-3-42 & ADDENDA

DATE: March 2, 1956

SUBJECT: HRT Oxygen Addition System

TO: Distribution

FROM: F. C. Zapp

CLASSIFICATION CANCELLED

DATE MAR 14 1957

For The Atomic Energy Commission

H. R. Canale
Chief, Declassification Branch TC

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Purpose

Oxygen is added to the circulating fuel system to prevent reduction of uranyl ions within the solution, and to prevent excessive corrosion of the stainless steel system. The oxygen is preferentially reduced rather than the uranium in solution. Addition of excess oxygen will also prevent excessive loss of D_2O since most of the deuterium will recombine with oxygen and will be recovered as D_2O . Excess oxygen is added only when the reactor is operated at low power levels and the quantity generated by water dissociation is inadequate. Oxygen addition facilities are also provided for the blanket circulating system in case other solutions replace the heavy water now used in the initial program.

Description

Present plans call for the addition of oxygen to the inlet or low pressure side of the fuel and blanket feed pumps. In this case standard oxygen cylinders will be used and the system is designed to add oxygen at a rate of 50 to 100 ppm. Cylinder gas at 2000 psi will be reduced to ~ 1500 psi at the accumulators and the metering system will reduce the pressure to ~ 750 psi. A 750 psi pressure is maintained to prevent fuel solution from backing up in the lines on a dump.

If it is necessary to add oxygen to the high pressure side (upstream of the feed pumps) the oxygen converter, which is capable of maintaining a pressure of 3000 psi, will be used. Oxygen will be added at a rate of 500 to 1000 ppm, and the accumulator pressure will be maintained at ~ 2500 psi with the metering system throttling to ~ 2100 psi.

The Instrumentation Section is conducting a series of tests to determine the maximum range of the metering and throttling equipment. Piping within the cell is designed with enough flexibility to allow switching from low to high pressure addition merely by blanking off one flange and bolting another. A radiation monitor will give warning if active solution should back up to the oxygen metering stations.

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An oxygen cylinder manifold and converter will be mounted outside in a partial enclosure to minimize handling and to provide a well ventilated location.

The converter consists of an insulated high pressure container with an electric heater and necessary controls to provide delivery of oxygen at a maximum pressure of 3000 psig. Delivery rate will, by means of a pressure switch, adjust to the demand over an approximate range of 0.1 lb. to 0.7 lb. per hour. The unit will be self containing and services required will be a supply of 110 V AC electric power, and the occasional use of a vacuum pump to maintain good insulation properties.

An inner, high pressure container is fabricated of type 304 stainless steel, and the outer vessel, or vacuum jacket is fabricated of carbon steel. The inner vessel is primarily supported by a stainless steel neck tube at the top, and lateral motion is prevented by three stainless steel wire spokes at the bottom. Five inches of Santocel is provided as the insulation between the inner and outer shells. A filter is built into the vacuum space to permit evacuation at any time without the loss of Santocel. A thermocouple type vacuum gage is utilized to indicate the absolute pressure in the insulation space. A cartridge type electric heater is provided for warming the oxygen at the rate necessary to maintain delivery pressure, and a pressure switch is provided to control the heater and maintain pressure between 2850 and 3000 psig. Converter pressure will be indicated by a bourdon type pressure gage. A helium thermometer is provided to show the inner container temperature and this temperature indicates the amount of oxygen remaining in the converter. When the temperature reaches 70° the design capacity of the converter is exhausted and the converter should be recharged.

A safety relief valve set for 3000 psig and a bursting disc safety head set at 4500 psig are connected to the high pressure piping, and a spring loaded

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safety disk is connected to the outer container to prevent damage in the unlikely event of an excessive pressure build up in the insulating space.

Design

The following reports, memoranda, and specification cover the basis of design for the oxygen addition system:

1. E. Youngblood, "Feed Pump Mockup", CF-55-2-52, dated 2-9-55.
2. S. Visner, "Oxygenation of HRT Solution", CF-54-7-34, dated 7-14-55.
3. R. Van Winkle, "Specifications for the Fuel Oxygenation System", CF-55-7-13, dated 7-1-55.
4. F. C. Zapp, "HRT Oxygen Addition System", (Memo) dated 11-11-55.
5. Specifications for High Pressure Oxygen Converter - HRT-1026, 4-5-55.
6. Proposal by Cambridge on "High Pressure Oxygen Converter Proposed to Meet Requirements of Specification HRT-1026."

Oxygen Requirements

A. Low Pressure Oxygen Addition

Assuming a minimum operating pressure of 750 psi; using standard oxygen cylinders as a source of supply (220 ft³-STP-at 70°F per cylinder - at 2000 psi); and assuming a 75 o/o utilization factor, we have a maximum operating pressure in the accumulators of 1500 psi.

The amount of oxygen available from one cylinder under the above conditions is $\left[\frac{2000}{220} = \frac{750}{x} \right] = \sim 82.5 \text{ ft}^3$, therefore when using 800 cc/min (STP - both systems) one bottle will last $\sim \frac{82.5}{3.53 \times 10^{-5} \times 800} = 2920 \text{ min.} = 48.7 \text{ hrs.}$

At this rate the four cylinders provided will last ~ 200 hours before replacement is necessary.

The oxygen station has four cylinders on service and four on standby so that one can switch oxygen supplies and then replace the depleted cylinders at a convenient time.

B. High Pressure Oxygen Addition

Oxygen Converter

Volume - 0.47 ft³
 Maximum pressure - 3000 psi
 Capacity - 30 lbs liquid oxygen

Assume addition of 1000 ppm

From CF-55-7-13

Oxygen required = $2.82 \times 1000 \times 1.5 = 4,230$ cc/min (STP)

For both blanket and fuel systems = ~ 8460 cc/min.

$$\frac{30 \text{ lb} \times 453.6 \text{ gr/lb}}{32 \frac{\text{gr}}{\text{mol}}} \times \frac{22,400 \text{ cc/gr mol}}{8460 \text{ cc/min}} = \underline{1125 \text{ min.}} = 18.8 \text{ hours}$$

If we assume a minimum pressure of 2100 psi, and a maximum use temperature of 70°F we have

$$n = \frac{PV}{RT} = \frac{2100(0.47)}{10.73(530)} = 0.174 \text{ lb mols } O_2$$

$0.174 \times 32 = 5.55$ lbs oxygen gas remaining in converter at recharging time.

If 5.6 lbs of oxygen remain, then $18.8 \times \frac{24.4}{30} = \underline{15.3 \text{ hours}}$ = length of time one charge will last at the usage rate assumed (8460 cc/min) and minimum pressure of 2100 psi. The converter specifications call for a maximum flow capacity of 0.50 lb/hr for a 24 hour period without refilling.

$$\frac{0.5 \text{ lb/hr} (453.6 \text{ gr/lb}) 22,400 \text{ cc/g mol}}{60 \text{ min/hr} \times 32 \text{ g/g-mol}} = 2650 \text{ cc/min}$$

At 2650 cc/min one charge would last $\frac{8460}{2650} \times 15.3 = 48.8$ hours

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If we assume an average usage rate of 2000 cc/min (STP) per system or 4000 cc/min, a 30 lb charge after initial charging of the accumulators will last approximately 32 hours. At this rate we would use approximately 159 lbs per week of continuous operation. The fuel system alone would require approximately 79 lb per week.

Liquid Oxygen

Handling and Filling

The hazards associated with the use of liquid oxygen; shipping and storage, precautions, and handling, are covered in National Safety Council Data Sheet D-283. This sheet covers the topic very well and copies can be obtained from the Linde Air Products Company.*

Procurement and Cost

Representatives of the Linde Air Products Company indicated that since our liquid oxygen requirements are small we would probably have to provide our own transportation facilities. They can provide Dewar vessels for transporting the liquid oxygen. Precautions should be taken to adequately vent the container and to prevent accidental breakage.

When transferring liquid oxygen, lines and valves should be kept free of moisture to avoid blocking due to ice formation. Release papers will have to be signed before delivery. In small lots liquid oxygen will cost approximately 40¢/liter = approximately 19¢/lb.

Initial System Cleaning and Testing

As pure oxygen under pressure may cause a violent reaction when it comes into contact with oil, grease, paint and similar materials, it is very important that the piping system used to distribute it be constructed so that all interior surfaces of the completed system are completely free

* Copies of this sheet have been ordered for the Operating Section.

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from these objectionable materials. To assure this, all pipe, pipe fittings, valves and outlet connection fittings, except those manufactured especially for oxygen service, should be washed thoroughly before use and kept clean in subsequent handling and assembly.

Steel pipe and all steel or cast iron fittings should be completely immersed in a hot solution of caustic soda and water mixed in the proportion of one pound of soda to one gallon of water. The duration of immersion will depend on the initial condition of the material and the degree of freshness and the temperature of the solution, but in any case must be sufficient to remove (after rinsing) all grease, oil, surface coating, or foreign materials.

All valves or fittings fabricated of, or containing parts of brass, bronze, white metal, and similar non-ferrous alloys subject to attack by caustic soda, should be disassembled and then scrubbed with, or immersed in, a hot solution of sodium carbonate or tri-sodium phosphate mixed in the proportions of one pound to three gallons of water. (An equal quantity of soda ash or 2.7 times as much sal soda may be substituted for the sodium carbonate.) The scrubbing should be thorough and include all surfaces. The immersion treatment should include continuous agitation of the parts and continue for at least ten minutes.

All screw connections made in attaching section shut-off valves should be "sweated" with soft solder. Both the pipe end and the valve opening threads should be thoroughly tinned and then assembled hot, precautions being taken to avoid heating the valve body enough to cause distortion. All other screw connections, except where noted otherwise on the drawings, should be made up with a thin paste of litharge and glycerine applied to the male threads only.

After the piping has been erected and connected, but before station outlet valves, separators or other equipment are attached, hammer the piping, particularly at welded joints, to loosen scale and blow out the line, using water-pumped compressed air from cylinders or oxygen from the manifold. Never use air from a shop compressed air system. Blow out each station drop separately, starting at the station farthest from the manifold. To do this effectively, cap all other outlets and attach a used gate valve (prewashed) to the pipe end of the station concerned, then open and close this valve repeatedly, alternately blowing off and refilling the line until the air or oxygen discharged is clear of dust or dirt particles.

After blowing out the line, attach station valves and separators and test the entire piping system for leaks at twice normal working pressure if possible. Test all joints with a greaseless soapy water solution, such as Ivory soap applied with a new or clean brush.

Paint all above-ground piping a distinguishing color such as the medium green used on oxygen equipment.

The above material was taken from a bulletin "Instructions for Design and Installation of Oxygen Distribution Piping Systems," by Linde.

Location of Installation and Piping

The oxygen cylinder gas and converter station is located on an outdoor concrete pad at the north-east corner of the 7500 building. Oxygen is piped inside the building to the East Instrument Cubicle and from there to the accumulators in the reactor cell. Two outlet lines from the accumulators enter the east cubicle, where the oxygen is metered and throttled, and then return to the reactor cell where they are piped to the feed pump inlet lines.

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Reference Drawings

<u>Dwg. No.</u>	<u>Title</u>
D-18292	Oxygen Metering Valve Assembly
TD-2688	Capillary Oxygen Meter
D-24721	Oxygen Metering Station Capillary Assembly
D-24719	Oxygen Metering Station - Fuel and Blanket Valve and Bracket Assembly
D-24729	East Cubicle Assembly
D-25508	Nitrogen-Oxygen Supply Station
E-18400	Inst. Air Lines for Control Room
E-2650-6-B(Cambridge)	Piping Assembly - 3000 psi Converter
E-2650-1-B(Cambridge)	General Assembly - 3000 psi converter

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1. Please delete the paragraph under "Purpose" (page 2) and replace with the following:

Oxygen is added to the circulating fuel system to prevent reduction of uranyl ions within the solution, and to prevent excessive corrosion of the stainless steel system. The oxygen is preferentially reduced rather than the uranium in solution. When the reactor is in operation, quantities of D_2 and O_2 gas are generated by radiolytic decomposition of the heavy water. Some of this oxygen is used in the formation of corrosion products in the system piping and equipment. This would result in a loss of D_2 and in order to avoid this, additional oxygen is supplied to recombine with the D_2 present to form D_2O . Oxygen addition facilities are also provided for the blanket circulating system in case other solutions replace the heavy water proposed for the initial program.

2. Under "Description" (page 2) change "be reduced to ~ 1500 psi", to "be introduced at the accumulators"

3. Under Oxygen Requirement (page 4) change to read as follows:

A. Low Pressure Oxygen Addition

Assuming a minimum introduction pressure of 750 psi, using standard oxygen cylinders as a source of supply (220 ft^3 -STP-at 70°F per cylinder - at 2000 psi); the amount of oxygen available from one cylinder under the above conditions

is $\left[\frac{2000}{220} = \frac{1250}{x} \right]$ and $x = \sim 138 \text{ ft}^3$, therefore when using 800 cc/min(STP - both systems) one bottle will last $\sim \frac{138}{3.53 \times 10^{-5} \times 800} = 4880 \text{ min.} = 81.3 \text{ hrs.}$

At this rate the four cylinders provided will last ~ 320 hours before replacement is necessary.

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