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POWER REQUIREMENTS OF DECOMPOSITION OF AIR
(Linde-Fränkl)

The modern Linde air decomposition installation was developed from the classical Linde installation for air separation by changing the heat exchanger composed of bundles of tubes to the Linde-Fränkl heat exchanger with aluminum inserts. The specific power requirements remained essentially the same, because the connections of the separating column remained essentially the same, with only minor changes.

Never the less noticeable reductions could of late be obtained in the power consumption by no longer compressing as formerly all the air supplied, (except for smaller amounts of high pressure air) to 5.5 atms. before being sent to the pressure column, but leaving part of this air uncompressed and introducing it into the upper column at atmospheric pressure.

This improvement was unexpected by outsiders and properly led the question whether additional reductions in specific power consumption could be achieved or whether this modification represented a last step in the development of the air decomposition and whether any further improvements in efficiency could be introduced only by improvements of the different parts of the installation, but leaving the scheme essentially unaltered. Such refinements might consist for instance in changing to shorter heat exchangers, possibly of larger cross section which would reduce the flow resistance, or also in eliminating the losses of cold.

To answer this question it would be necessary to calculate the minimum power requirement with which a decomposition of air just becomes impossible. This will simultaneously give the most favorable arrangement of the connections.

We are here communicating the results of such computation of the minimum power requirements which will be obtained when the thermodynamic losses, resulting from temperature differences and from other causes, are kept at a minimum.

Let us assume the presence of a temperature difference at the two sides of a condensor, required for transferring larger amounts of heat from the compressed air column to the column at atmospheric pressure. The temperature difference determines also the pressure in the compressor column, which is equal to 5.8 atm. in the Leuna installation, and correspond to a temperature difference of around 5°. Increasing the condensers will result in reducing the temperature difference, and also correspondingly the pressure in the compressor column. A zero temperature difference corresponds to a pressure of

3.5 atm. The heat transfer at t=o requires however an infinitely great heat transfer surface. This is the reason why such process cannot be actually introduced, although it remains theoretically possible. On the other hand, pressures lower than p=3.5 atm. cannot be conceived physically, because heat cannot travel in a direction opposite to the temperature drop.

The zero temperature difference represents a limiting value with the lowest power consumption.

In analogy to the drop in temperature as the driving factor of heat exchanger, the transfer of material in the separatory column is caused by a difference in partial pressures.

For this reason, an analogy with the zero temperature difference, the following assumption is put at the basis of computation of the difference in partial pressure between gas and liquid being equal to zero in the following places:

1. in the sumps of the two columns,
2. at the top plate of the two columns,
3. at the intermediate plate of the atmospheric pressure column on which (a) the liquid oxygen is given off in the pressure column, and (b) air is given off.

Equilibria will be reached in the exchange of material between gas and liquid in these cross sections.

Furthermore, the temperature of the incoming air should equal that of the oxygen and nitrogen being evaporated during the heat exchange, keeping the temperature difference at this place equal to zero. In another cross section of the heat exchanger the temperature difference must again become zero but at a lower temperature. This last requirement furnishes us precise information on the pressure of the high pressure stage.

The losses of cold must be set equal to zero, and the loss in pressure resulting from the resistance of the heat exchanger as well as from the level of the liquid on the plates of the distillation column may also be neglected.

The values given in the table below per 1000/m^3 of pure oxygen have been obtained on the assumptions made above.

Specific Power Requirements of Different Linde Air Decomposition Installations for 1000/nm^3 oxygen.

Designation	Units	Theoretical installation with the minimum power requirements	The Anschwitz installation	Leuna installation
Low pressure air *	Mol/Mol	0.266	0.167	—
Pressure of the low pressure air	Atm.	1.0	1.45	—
Intermediate pressure air *	Mol/Mol	0.705	0.872	1.026
Pressure of intermediate pressure air	Atm.	3.5	5.8	5.8
High pressure air*	Mol/Mol	0.029	0.071	0.074
pressure of high pressure air	Atm.	143	185	185
Cold production with Ammonia *	Kcal/Mol	1.0	22.2	23.2
Total air *	Mols	1.00	1.116	1.100
Power Consumption Isothermal = 1.0 Low pressure air	Kw.	0.0	8.0	—
Intermediate pressure air	"	114.5	193.3	234.2
High pressure air	"	18.8	47.8	50.1
Ammonia Compression	"	0.1	1.7	1.7
Expansion Engine ad = 1.0	"	—	26.7	3.8
Power consumption total	kw/1000 nm^3 oxygen	133.4	221.1	282.2

* Referred to one mol of air drawn in at theoretically complete decomposition.

The above value for the specific power consumption may be compared with a fourth value, obtained from an entirely different physically conceivable process of air separation. We might have air compressed in a engine the piston of which is permeable to either oxygen or to nitrogen molecules alone. With such a compressor the air could be decomposed reversible into its two elements. The specific power requirements of the machine would amount to 67 kw/1000 m3 of oxygen. It is therefore considerably lower than the power requirements of the theoretical Linde installation. The unfavorable decomposition of the Linde installation results from the completely reversible compression, while the heat and the material exchange in the Linde installation proceed irreversibly and are therefore bound with losses which require additional expenditure of power.

The specific power requirement of the Linde installation with the least power consumption amounts to about 1/2 of those of the Linde installation in Auschwitz or Leuna. This is to be attributed in the first place to the assumption of no temperature differences during the heat exchange of large amounts of heat in the minimum condenser of the installation, and therefore without losses. Were we to assume here the same temperature differences as in the operations in Leuna, the specific power consumption would immediately increase by around 40 kw/1000 m³ oxygen to over 170 kw, and become therefore closer to the value in Auschwitz.

A comparison of the connections in the separatory column of the theoretical installation with the one in Auschwitz leads to the conclusion that no further great reduction in the specific power requirement can be obtained by any improvements in the arrangement of the connections, but that small improvements of a few percent in the power requirements may be still possible.

The cost of power is the principal item in the production cost of oxygen, and amounts to over 50% of the total, and no cheapening of oxygen by a further reduction in the power consumption is possible. The amortization of the installation amounts to about 25% of the production costs and the rest of the costs are labor and maintenance of the installation. Only a change to larger units, such as are in use in modern hydrogenation could somewhat lower three last mentioned items of costs: amortization, wages and repairs. Linde is however but little interested in the retooling required for the relatively few large unit, because this firm operates in Germany without competition.

One may not therefore expect any great cheapening in the production of oxygen by any technical means.

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Summary

The specific power requirements of Linde installation in Auschwitz are about 10% lower than of the Linde installation in Leuna. A determination was made whether further material lowering of the specific power requirement are possible by calculating the specific power requirements of a theoretical Linde installation operating under limiting conditions which would just make the Linde process physically impossible in practice because of the too large dimensions.

A comparison of the three processes shows that the specific power requirements may be lowered but slightly and that a further cheapening of oxygen can only result by reducing amortization, that is by making larger and cheaper installation units.

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