

# The Quality of Compressed Air as the Necessary Condition the Improving the Process Efficiency in Foundry Plants

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## Abstract

A foundry plant as a manufacturing system operates in accordance with the methods and principles making up the entire process of casting production, involving the use of machines and installations. One of the factors transforming the foundry plant's static structure into the dynamic –processing structure is the compressed air. Practically each procedure making up the casting manufacturing process involves compressed air. Its sources include compressor machines connected to the receiving tanks, making up the compressed air transport installation. Two major aspects are to be addressed in compressed air management: the engineering and economic ones. The engineering aspect involves the manufacturing of compressed air with the required quality features and in the amount balancing its demand, whilst the economic aspect is associated with cost minimisation. This paper investigates the engineering aspects: air quality, with the main focus on air treatment processes to satisfy the constructional and operational requirements of air receivers present in the casting processes.

**Keywords:** Compressed air, Foundry technologies

## 1. Introduction

A characteristic aspect of foundry engineering is the complexity of involved processes, demonstrated by the set of methods and principles governing the operation of manufacturing and material handling teams implementing the subsequent processes of casting production. This complexity is further enhanced by the various types of installed power sources, which determine the dynamic structure of the manufacturing processes.

Among the three types of power sources: electric, hydraulic and pneumatic, compressed air plays a very important role. The sources of compressed air include compressor machines, which, together with the piping installation, constitute the transport system from the source to the receiving tanks. In the context of

design engineering, compressed air installations are configured in closed-loop and branched networks, to facilitate their transmission to any reception points. Another feature is the feasibility of its storage in tanks (equalizing tanks), without essential changing the physical and chemical parameters of air. This storage capability is of primary importance in systems which are not in constant operations or which operate under variable loading (demand conditions) and in the conditions of interrupted power supply to the drives of compressor machines.

In foundry plants compressed air is used in modern machines and installations, in transport systems and in measurement and control equipment. It is required to perform the machine- steering function, the driving function and to cause the change of physical and chemical conditions of materials. Because of the diversity of processes and constructions involved and the differences in

operating conditions of air receiving tanks, the quality of compressed air becomes the key requirement. It is typically defined as the degree of purity in terms of water contents, the presence of dust contaminants, products of corrosion, oils and oil aerosols. The process of compressed air manufacturing and treatment is one of the factors prompting the advancement of new technologies in foundry engineering.

## 2. Technological system of a foundry plant

In accordance with the general principles of the theory of systems, a foundry plant is a technological system including [1]:

1. Process section- whose operation is underpinned by the set of methods determining the unit processes of material processing to yield the finished product- a casting.
2. Technological and machine section – comprising the machines, installations, transport systems and equipment.

The process section is defined by the technological structure of casting manufacturing. Recalling the concepts of functional analysis, the following partial processes are distinguished:

### a) preparation of moulding sand and core sand

Because of the specificity of moulding sand materials, the sand preparation is required when handling synthetic moulding sand with bentonite and moulding sands containing various binders. In the case of moulding sand containing bentonite, the two processes are involved: fresh (green) moulding sand circulation and return moulding sand circulation. The first process line involves the dosing of moulding sand components to the mixers and their mixing and conveying the ready-made moulding sand to the moulding stations. The process line for handling the return sand begins with separating the casting from the mould (knocking-out), reverse transport, cooling or full homogenisation for rebonding.

In the process technology using moulding sand with binders, there are two lines: for handling fresh sand and sand mix knocked out to be reclaimed. The following functions are implemented:

#### fresh moulding sand line:

- dosing and mixing of sand mix components (fresh sand and reclaimed sand, binder, hardening agent, catalyst)
- moulding sand dosing to the moulding boxes

#### return sand line:

- knocking-out
- preparation for reclamation and reclamation
- conveying the reclaimed sand by pneumatic systems for reusing

### b) core and mould manufacturing

The process consists of compaction the moulding sand to form the mould.

The green sand mould are made by:

- jolting and squeezing in flasks
- air flow processes (over pressure and vacuum methods) in flasks

- shooting and squeezing methods (vertical or horizontal parting line of the mould – flaskless moulding)

Moulds and cores containing moulding sand with binders are manufactured by:

- vibration
- blowing
- shooting.

### c) knocking-out of expendable moulds

The process involves the destruction of moulds after separation from castings, by the following techniques:

- shaking and vibration
- mechanical pushing (for example with the next vibration)
- pneumatic methods

### d) pouring into permanent moulds (metal moulds, gravity dies)

Operations involved in the process:

- mould assembly and shutting off
- locking (to prevent its opening)
- opening and removing the castings

This overview of partial processes is not complete as the analysis is restricted to processes in which compressed air is used.

Another vital aspect of the process line is the equipment (machines and installations) required for manufacturing castings. In the context of engineering design, this equipment determines the production capacity and optimal use of the plant's capacity [2].

The foundry plant incorporates the following structures:

- a) workplace structure: its integral component being a single machine, such as a moulding machine operated by the jolting and squeezing method and performing the following functions: jolting, squeezing or performing the combined cycle, controlling the plate arm extension, mould separation process.
- b) cells structure: based on the automatic moulding system and simple conveying units. Its main functions: flask filling, sand compaction by mechanical or pneumatic methods, separating the mould from the pattern plate and other functions required in the process line.
- c) structure of mechanised and automated moulding line: comprising the machines and conveying systems required for castings manufacturing processes. Its main functions include: mould making, turning the half moulds, assembly, protection against mould opening under the action of metalostatic pressure, conveying, shifting.

## 3. Overview of key stages of the manufacturing process utilising compressed air

- a) Mould and core making, involving the following functions:
  - sand dosing (the stream of moulding sand and air, concentration)
  - compaction (filtering, pre-compaction, air pressure)

- blowing (filtration, concentration, pressure)
  - shooting (pressure, filtration, concentration)
- b) Pneumatic transport systems- low, medium and high pressure installations. Two options are available:
- batch – by batch transport (dense phase)
  - continuous (full pipe) transport
- c) Operation of implements and actuating mechanisms; the distinguishing feature being their structural design, kinematic and dynamic characteristics. The following categorisation is given, depending on their functions:
- vibrators, producing the vibratory motion with the predetermined amplitude and frequency
  - actuators, inducing the reciprocating motion defined by the such parameters as force and stroke [3]
  - working tools: being the sources of rotary and impulse motion
  - mechanisms, manipulators, crane installations, process lines perform the specified tasks: lifting, positioning, rotating, setting the mechanisms in motion (broadly understood), shifting, powering, controlling, compaction, knocking-out
  - control elements, including position control functions and interlocks
- d) Air protection inside the foundry plant: dust removal and ventilation. The following aspects are addressed:
- identification of dust sources (technical characteristics of emission sources, physico-chemical analysis of gases)
  - dust removal as a process and solution to a problem
  - individual and central ventilation
  - pertinent calculations (air balance)
- e) Casting painting for corrosion protection and for adornment purposes, involving:
- finishing and surface preparation
  - coating

## 4. Analysis of processes using compressed air

1. Air contact with core and moulding sand
  - a) in the case of synthetic moulding sands containing bentonite, the following processes will take place:
    - filtration (jet concentration), adverse effects of water, (air humidity), oils and emulsions
    - pressures experienced in the process of sand conveying, filling of the technological space (flask, box filling, filling of the shooting chamber)
    - deterioration of moulding sand strength
    - increased water content
    - increased amounts of gaseous substances (that occur during the mould pouring)
  - b) in the case of moulding sands containing binders, the following processes will take place:

- pressures (concentration of air-sand jet, adverse effects of water, oils and emulsions)
  - deteriorated sand durability
  - deteriorated sand strength
  - increased water content
  - increased amounts of gaseous substances (that occur during the mould pouring)
2. Dynamic quantities, for instance those associated with the pressure levels [3]
  3. Kinematic parameters: geometry of motion, positioning and other time-dependent parameters
  4. Functionality (correct operation) in the mechanised, automated structure involving robots: quantitative and volumetric air demand
  5. Flows and capacity in the geometric structure of the piping installations

## 5. Compressed air quality criteria

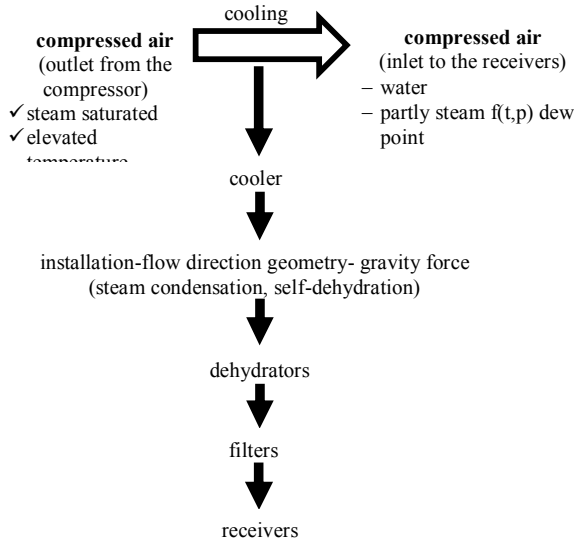
Three categories of quality criteria are considered:

- a) design objectives and requirements
  - characteristic of air sources: the critical value being the compression  $\varepsilon < 3$  (the ratio of the inlet to the outlet pressure). In the range  $< 3$ : fans and blowers,  $> 3$ : compressors [5]
  - characteristic of receiving sources, in consideration of their operational parameters associated with the type of manufacturing processes
  - spatial structure of locations of compressed air sources and receiving devices
  - structure of the network of conduits connecting the sources to the receivers, including the air treatment units. In consideration of the optimal length criterion, the network can be designed as branched or closed.
- b) Output parameters of compressed air[4]
  - increased temperature: compressors are included in the group of thermal machines, by virtue of gas processes involved in compression
  - level of pollution: the sources of pollutants: outside conditions (air suction) and internal conditions (pollutants generated in the compressors)
  - moisture content, depending on the conditions of sucked-in air
  - increasing of the pressure levels in relation to that required in the tank; it is necessary because of flow resistance and volumetric losses in air transport installation
- c) The required parameters of compressed air to be used in the receivers [4]
  - moisture content (water elimination and drying)
  - level of the heating: temperature reduction
  - purity (removal of contaminants)
  - others (for example ensuring the required lubrication property)

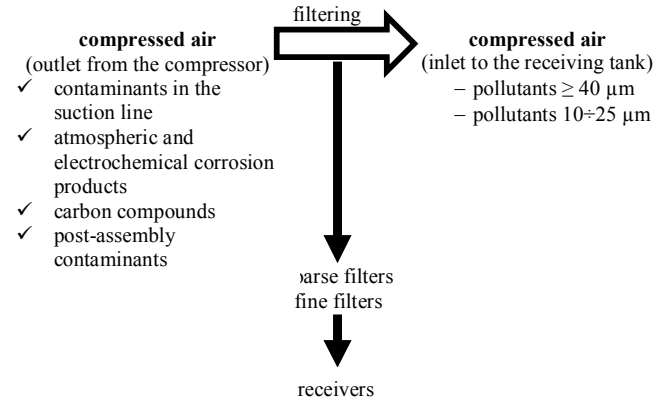
## 6. Operations changing the compressed air quality

The condition of compressed air at the outlet from the compressor (left-hand column) are shown in schematic diagrams. The operations performed to modify the air properties are listed in the middle column and the air condition after treatment – in the right-hand column.

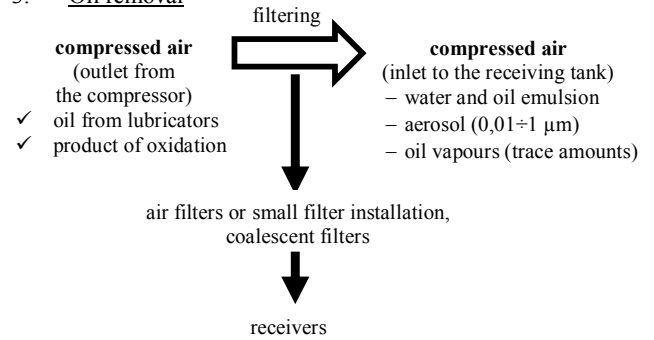
### 1. Water removal



### 2. Removal of contaminants



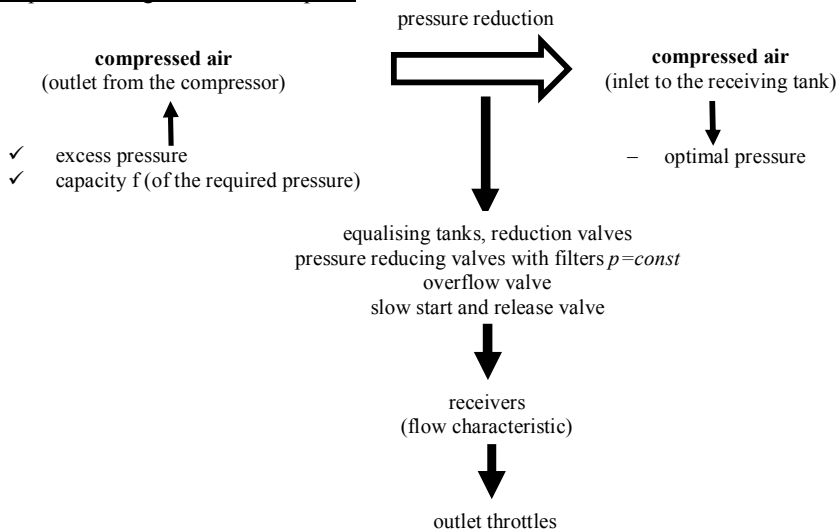
### 3. Oil removal



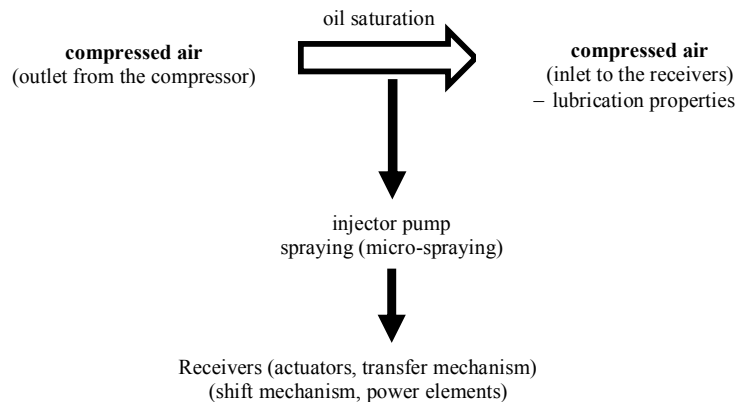
#### Recommended filtration levels

Foundry machines	Oil 4	Contaminant 5
Pneumatic tools	Oil 5	Contaminant 5
Pneumatic cylinders	Oil 3	Contaminant 5
Process control systems	Oil 2	Contaminant 3
Spray-painting	Oil 1	Contaminant 1

### 4. Pressure control-protection against excessive pressure



## 5. Improving the lubrication properties



## 7. Summing-up

Compressed air as one of the power sources widely used in foundry engineering has to satisfy the relevant quality criteria. Produced in compressor machines, it contains pollutants which vastly preclude its direct use in processes. Typical pollutants include water and dust particles and the conditions are further aggravated by too high water content and increased temperatures. Recommended processes (cooling, filtering, dehydration, drying, pressure reduction) and the use of dedicated system components ensure the required quality of compressed air. Since compressed air in several processes has direct contact with the materials (such as moulding materials) or is used to drive the mechanisms, all efforts have to be undertaken to improve its quality in order to optimise the manufacturing processes in foundry plants.

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