Design and making of a MAF Sensor based flow bench

FORMULA
UOTTAWA

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Contents

1 Introduction

This report covers the development of a flow bench to test the intake of the GGR26's and will be used to optimize said intake. The report will cover the following subjects:

1.1 Objectives

1. Develop a flow bench for the purpose of measuring airflow through a test piece
2. Validate the results of the flow bench
3. Optimize the GGR26's based on airflow measurement from the flow bench

2 Theory

Flow benches are primarily used in the automotive industry for the optimization of cylinder head porting as they can measure gains or losses in airflow. Besides cylinder heads, flow benches could also be used to measure airflow through other engine and powertrain parts such as carburetors, throttle bodies, or in our case, intake manifolds [1].

There are multiple ways to measure airflow; however, they all rely on measuring the pressure drop across the test piece. In other words, the measured pressure before and after air enters the test piece. We will be using a MAF sensor, meaning we will be finding the Mass Air Flow, therefore finding the CFM is not required.

2.1 Orifice Plate

The orifice plate is the chosen method for many modern flow benches. The orifice plate has a small, precisely machined hole which air passes through [2]. The pressure drop across the plate as air passes through it is proportional to the airflow thus ΔP can be used to calculate CFM via the specific ΔP vs CFM curve provided by the manufacturer.

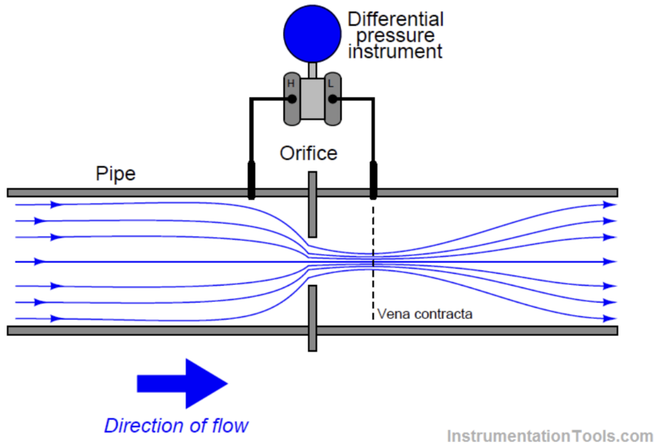

Figure 1: The working principle of an orifice plate
[3]

2.2 Laminar Flow Element

A laminar flow element (LFE) is a bundle of tubes or an array of specially machined honeycombs that force laminar flow. The laminar flow allows for more consistent pressure readings. The pressure drop (ΔP) across the LFE is proportional to the airflow is calculated using a method similar to the one discussed in section 2.1 about orifice plates.

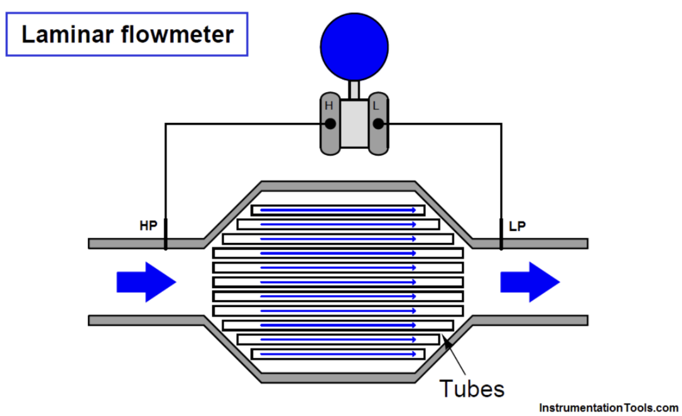

Figure 2: The working principle of a laminar flow element
[3]

2.3 Sensor Based Approach

The sensor based approach depends on a Mass Air Flow (MAF) sensor. The MAF sensor works by heating a thin wire using electrical current. The heating is governed by Joule's Law of Heating, $P = I^2R$, which describes how much heat power is generated in a conductor when current flows through its electrical resistance.

As air passes through the sensor, it cools the hot wire or film. The sensor's internal electronics continuously adjust the current to keep the element at a fixed temperature above ambient [4]. Increased airflow removes more heat, so the circuit must supply more electrical power to maintain the target temperature. This creates a direct, measurable relationship between airflow induced cooling and the electrical current. The sensor converts this relationship into an output signal proportional to the mass flow rate of the air.

A differential pressure sensor is required to measure the pressure drop across the test piece, which is essential for determining airflow in a flow bench. The differential sensor has two ports, one connected to the upstream side of the test piece and one connected to the downstream (low-pressure) side. It directly measures the pressure difference (ΔP) between these two locations. This pressure drop is what drives airflow through the test piece, and its magnitude is used to characterize flow at standardized test values (such as 28 inches of water or 9.25 psi).

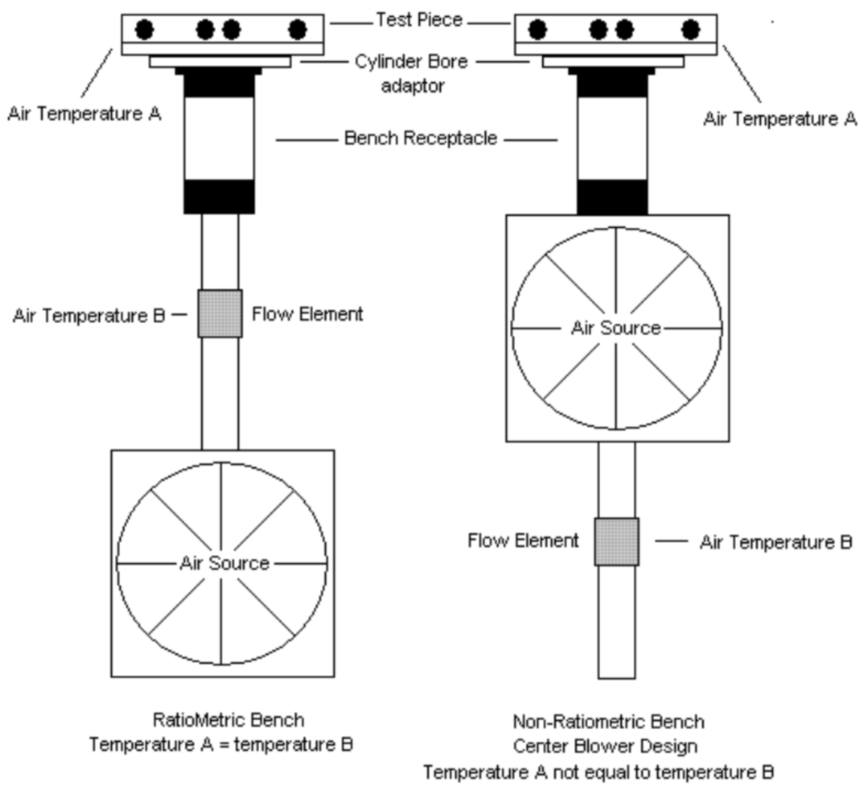

Figure 3: A diagram comparing ratiometric vs non-ratiometric designs [5]

2.4 CFM Calculation

First we measure the pressure drop across the test piece using the differential pressure sensor

$$\Delta P = P_{\text{upstream}} - P_{\text{downstream}} \tag{1}$$

The absolute pressure sensor in the plenum lets us compute the air density and the stability of the vacuum source. From the MAF sensor we get the mass flow rate, $\dot{m}$. To convert mass flow to volumetric flow the following equation is used:

$$\text{CFM} = \frac{\dot{m}\ (\frac{kg}{second})}{\rho\ (\frac{kg}{m^3})} \times \frac{60 \text{ seconds}}{1 \text{ minute}} \times \frac{35.3147 \text{ ft}^3}{1 \text{ m}^3} \tag{2}$$

where CFM refers to Cubic Feet per Minute, $\dot{m}$ is mass flow and ρ is the air density. $\dot{m}$ is generally given in $\frac{kg}{s}$ so a conversion factor of $\frac{60 \text{ seconds}}{1 \text{ minute}}$ is applied. Overall, these equations are necessary for evaluating and comparing different test pieces as they explain the behavior of a test piece by providing the amount of air flowing (CFM) at a given ΔP [6].

3 Design

The flow bench consists of an Absolute Pressure Sensor (APS) to compute the air density, a differential pressure sensor to obtain the pressure drop across the test piece and a MAF sensor to compute the amount of air flowing through the test piece [7]. Equation (1) is used to compute the ΔP across the test piece and Equation (2) is used to compute CFM.

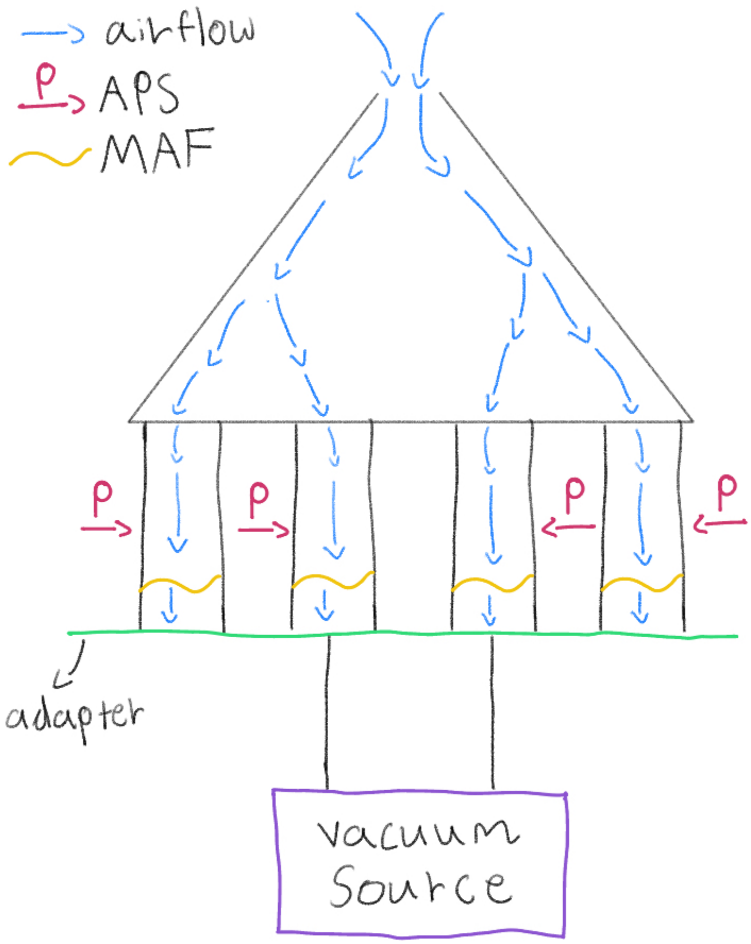

Figure 4: A diagram depicting how a sensor based flow bench would flow an intake manifold

The air source has to be bi-directional, meaning that the air has to flow in both directions. In this way, we could have positive pressure for exhaust ports and negative pressure for flowing the intake manifold. The air source would most likely be a shop vacuum or a home vacuum motor. A shop vacuum motor despite its size, is worse for flow benches due to their blower shroud being affixed to the motor. This means we would not be able to remove the motor. If we were to use a motor, we would need the household vacuum motor. On the other hand, connecting a shop vacuum to the flow bench would work as well. This way, we would not need to make our own vacuum with motors, although there is less control and power (check if this is true and even relevant). While it may seem a shop vacuum may appear to have a stronger motor, that is not the case [8].

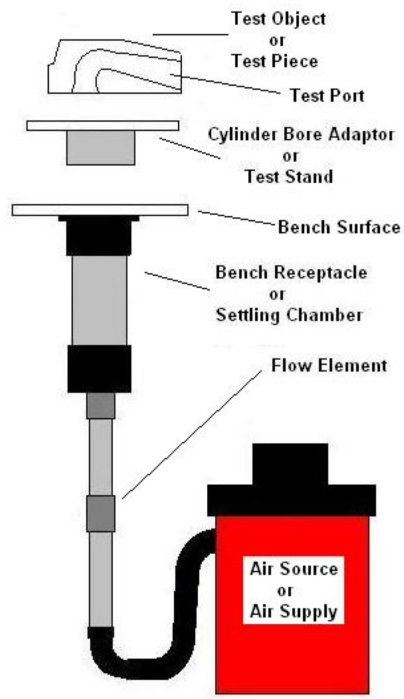

Figure 5: Flow bench with a shop vac
[5]

If we were to use motors as our air source, we would need to construct a box to house the motors. We could create the box with wood pieces, combine with silicone to create an air tight seal. Another option could be taking a tote box, supporting it with wood, and again using silicone. If we were to use a shop vacuum, this step would be skipped, and we would need an adapter for the flow element.

The MAF sensor would come after the flow element, and would be connected to a series of electronics, combined with the pressure sensors. This is the main portion in our flow bench. It

3.1 Cost

4 Manufacturing

5 Testing

6 Results

References

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