

Image Processing

An Experimental Analysis of Image Processing in Fluidic Process

by

Abhijeet Bangalore Shasedhara

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Approved March 2011 by the
Graduate Supervisory Committee:

Taewoo Lee, Chair
Huei-Ping Huang
Kangping Chen

ARIZONA STATE UNIVERSITY

May 2011

ABSTRACT

Image processing in canals, rivers and other bodies of water has been a very important concern. This research using Image Processing was performed to obtain a photographic evidence of the data of the site which helps in monitoring the conditions of the water body and the surroundings. Images are captured using a digital camera and the images are stored onto a datalogger, these images are retrieved using a cellular/ satellite modem. A MATLAB program was designed to obtain the level of water by just entering the file name into to the program, a curve fit model was created to determine the contrast parameters. The contrast parameters were obtained using the data obtained from the gray scale image mainly the mean and variance of the intensity values. The enhanced images are used to determine the level of water by taking pixel intensity plots along the region of interest. The level of water obtained is accurate to less than 2% of the actual level of water observed from the image.

High speed imaging in micro channels have various application in industrial field, medical field etc. In medical field it is tested by using blood samples. The experimental procedure proposed determines the flow duration and the defects observed in these channel using a fluid introduced into the micro channel the fluid being water based dye and whole milk. The viscosity of the fluid shows different types of flow patterns and defects in the micro channel. The defects observed vary from a small effect to the flow pattern to an extreme defect in the channel such as obstruction of flow or deformation in the channel. The sample needs to be further analyzed by SEM to get a better insight on the defects.

ACKNOWLEDGMENTS

I would like to thank my advisor Dr. Taewoo Lee for his endless support, encouragement, guidance, and advice without which my research wouldn't have progressed in the right direction. I would also like to thank my committee, Dr. Huei-Ping Huang and Dr. Kangping Chen for their support.

I would also like to thank the Department of Mechanical engineering at Arizona state university for providing me this opportunity to pursue my education in this esteemed university.

Lastly, a special thanks to my parents and friends especially Monica Shekar for their continuous support and blessings for the work I choose to pursue.

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Chapter 1

BACKGROUND AND LITERATURE

1.1 Image processing model.

Image processing can be summarized as ‘a process which takes an image input and generates a modified image output’. Image analysis is normally satisfied with quantifying data about objects which are known to exist within the scene, scene analysis was the term used initially before the term image analysis was introduced which was fundamentally based upon the physics of image formation and operation of the image acquisition system.

The image processing operations are used to modify the array of stored image data to better serve the intended purpose. The image processing operations are categorized into two categories, low level and high level. Low level operations are used to modify the stored image data as needed, as for the latter it is concerned with the analysis, description and understanding of images.

The image processing model involves a step by step method which is used in problem solving. The necessary function of an image processing model can be identified as.

1. The exploitation and imposition of environmental constraints.
2. The capture of an image.
3. The analysis of that image.
4. Actions taken as a result in order to complete a task at hand.

The image processing model can be illustrated as shown in the figure below. The model identifies several elements or also known as sub systems.

Figure-1

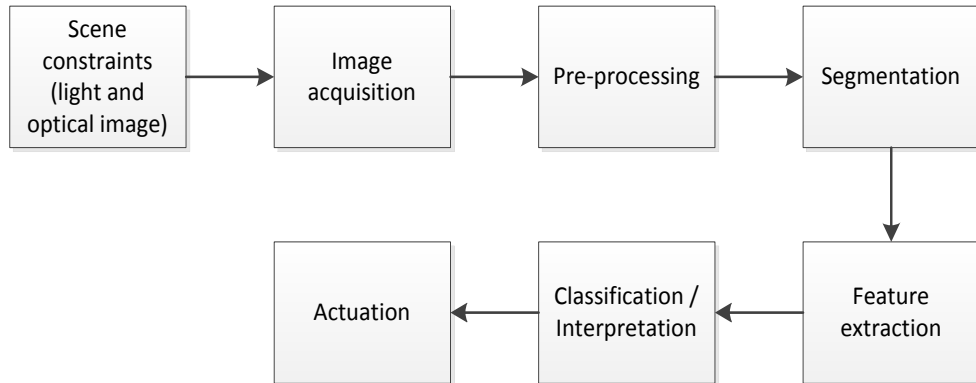


Image processing model (Ref – G.J. Awcock and R. Thomas)

Scene constraints

The first and most important element is identifying the scene constraint, the scene refers to the region of interest or the field of view of the image. The aim of the scene constraint is to reduce the complexity of the model, this is achieved by making sure the lighting conditions are suitable, the field of view is clear, lighting being the most important concern.

In an industrial environment the lighting conditions and placement of the camera are controlled to obtain the best results. In addition to lighting conditions other factors which might come into effect are dirt, dust and environmental conditions come into effect while controlling the scene constraint.

Image acquisition

This element in the model is concerned with the process of translation of light falling on to the camera's photo sensors to a stored digital value within the storage device. A digital image can be of any pixel resolution with each pixel

representing a binary, gray scale or a color value. A digital camera uses a CCD (charged coupled device) to convert light stimuli into a digital value.

Preprocessing

This element seeks to modify and prepare the pixel values of a digital image to a more suitable image for processing. Generally contrast enhancement and adjustment, noise reduction and improving the quality of the image is done during this stage. These operations only change the pixel values of the stored image and do not make any fundamental changes to the image.

Preprocessing operators act on the spatial domain, this is usually concerned with a specific pixel value or a small number of neighboring pixels. Operations which are required to act globally on the image often make use of transformations. The most commonly used transform is the Fourier transform. Low level operations generally highlight particular feature of interest. Histogram manipulations are used to adjust the intensity levels of the image depending on whether the intensity levels are on the lower or higher side, this usually enhances or suppress the contrast and stretch or compress the grey levels without any change in the image data.

Segmentation

This is the initial stage of image recognition process where the acquired image is broken down into meaningful regions. Segmentation is only concerned with the process of partitioning the image and not concerned about what the region represents. In binary images there are only two regions a foreground region and the background region, in a gray scale image there might be several regions

or classes within the image. Image Segmentation consists of two main approaches namely thresholding and edge based methods.

Thresholding techniques can be employed either on a global or local methods. In global thresholding the entire image is thresholded with a single threshold value, whereas in local thresholding technique an image is partitioned into smaller regions and determines a threshold to these smaller regions.

Edge based segmentation begins with edge enhancement which makes use of standard finite difference operators, the first order gradient operators, the second order laplacian operator. The operation enhances intensity changes and transforms the image into a representation form.

Feature extraction

It is an important function before prerequisite to classification process. In this process features of different regions within the image are identified. The characteristics of an image are extracted and obtained such as size, position, number, area etc.

Classification

The classification process is a successor of feature extraction, it is concerned with the process of pattern recognition or image classification. It uses the data extracted from the image to make an accurate decision as to which category the pattern belongs to.

Actuation

The actuation property provides a means of closing the loop and allowing interaction with the original data.

1.2 Optics.

The digital images are captured by focusing the camera on the object. The camera is focused using a lens which is used to project the object on to the photo sensor in the camera. The size and resolution of the sensor will affect the design of the lens system.

The basic formulae used to calculate the correct focal length to achieve a given magnification or to predict the effect of change in the focal length are given below.

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$m = \frac{v}{u}$$

$$f = \frac{um}{(m + 1)}$$

$$n = \frac{f}{d}$$

Where f is the focal length of the lens, u is the object to lens distance, v is the image to lens distance, m is the magnification defined as image size is divided by the object size, n is the numerical aperture or (f number) of the lens and d is the diameter of the lens aperture.

For designing a suitable lens the following are taken into consideration.

1. Defining the field of view, defining how much of a scene and level of detail are to be captured.
2. Controlling the amount of light passing through to the image sensor so that the image is correctly exposed.

3. Focusing by adjusting either elements within the lens assembly or the distance between the lens assembly and the image sensor.

Field of view

This is the area of coverage and the degree of detail to be viewed. The focal length of the lens is defined by the distance between the entrance lens and the point where the light rays converge on the image sensor, this implies the longer the focal length the smaller the field of view.

The fastest way to determine the focal length of the lens required is by using the expression given below

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

There are three types of lenses, fixed lens which has a fixed focal length i.e. only one field of view, Varifocal lens this type of lens offers a range of focal lengths hence the field of view can be manually adjusted. Zoom lens are like varifocal length enabling to select a different field of view, in zoom lens however there is no need to focus the field of view for specified range of focal length.

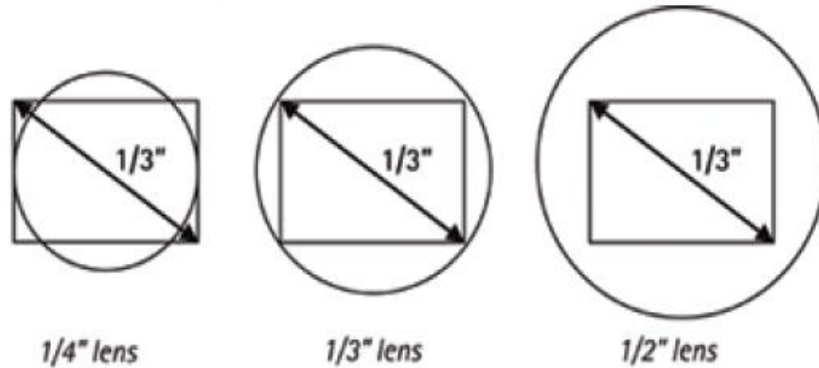
Photo sensors

A camera's lens can be interchanged as desired, however the size of the photo sensor installed in the lens should be considered to choose the right type of lens. If a lens is made for a smaller image sensor than the one that is actually fitted inside the camera, the image will have black corners. If a lens is made for a larger image sensor than the one that is actually fitted inside the camera, the field of view will be smaller than the lens capability since part of the information will

be “lost” outside the image sensor. A description of the lens size and image sensor is shown in the figure below.

Figure-2

Examples of different lenses mounted onto a 1/3-inch image sensor.



Lens and mount sensor-(Ref-Axis communication lens elements)

Lens mount and standards

While choosing the lens for the camera the type of mount on the camera needs to be considered it is a very important factor. There are two main standard type of lens mounts C-mount and CS-mount for a Closed circuit camera or network camera. The difference between the two types of lens mounts is.

CS-mount- The distance between the sensor and the lens should be 12.5mm.

C-mount- The distance between the sensor and the lens should be 17.526mm.

A C-mount lens can be used on a CS-mount using a 5 mm spaces known as the C/CS spacer.

The image quality is determined by the amount of light entering the lens and exposed onto the photo sensor, this is determined by the f-number of the lens, the f-number of the lens is determined by the ratio of ‘focal length to the iris diameter’. The equation to calculate the f-number is given below.

$$n = \frac{f}{d}$$

The smaller the f-number the better the lens' light gathering ability i.e. more light can pass through the lens to the image sensor. In lowlight situations, a smaller f-number generally produces a better image quality.

1.3 Contrast stretching.

A pixel operation is one in which the output image is a function of the gray scale values of the pixel at the corresponding position in the input and only of that pixel. The point (pixel) operation is interpreted using the gray scale histogram. This histogram represents the frequency of each gray level intensity.

The image brightness is adjusted by observing the histogram of a gray scale image. If the intensity values are concentrated on end of the range the brightness of the image can be increased or decreased by adding or subtracting a constant from all pixel intensity values stored in a array. The brightness modification can be represented by a simple expression.

$$P' = P + A$$

Where, P' is the pixel value after enhancement.

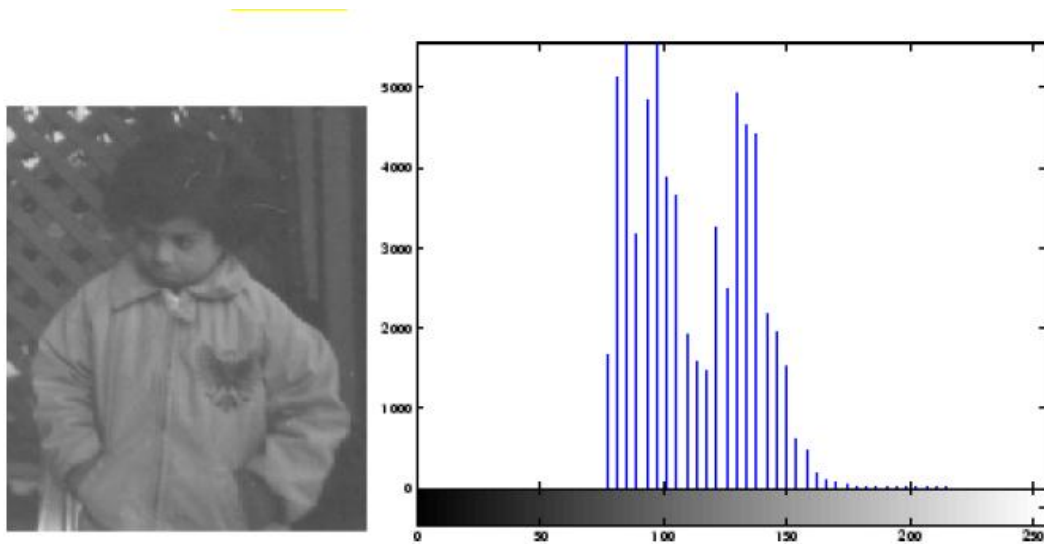
P is the pixel value before enhancement.

A is the enhancement factor.

The above expression just increases or decreases the brightness of the image. There is no alteration to the distribution of pixel intensity values in the histogram hence there is no alteration in the contrast.

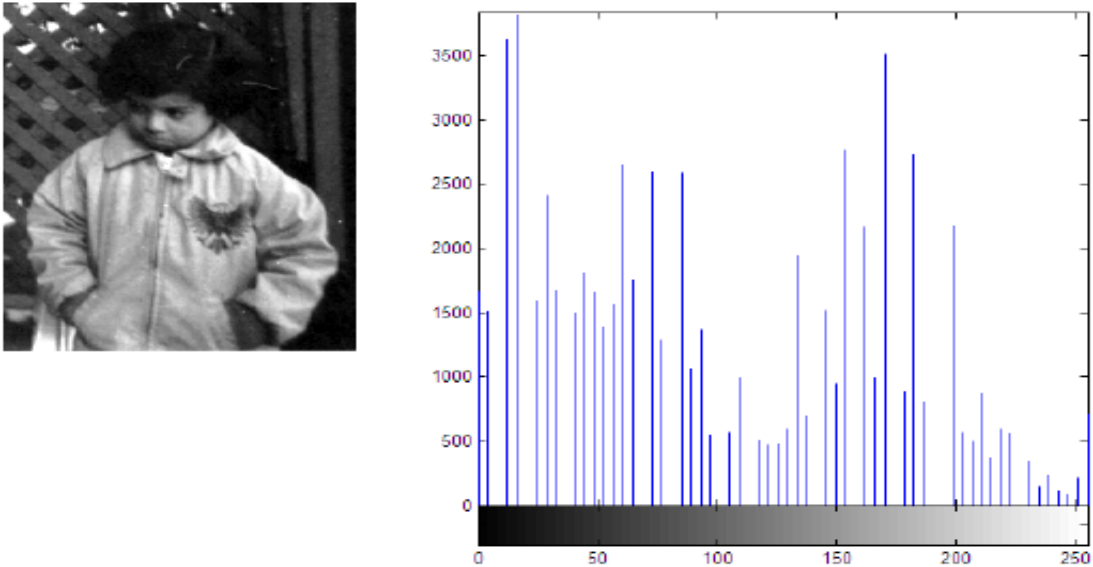
This can be improved by gray level scaling where a multiplication operation is used for stretch the histogram to cover the complete range of gray level values. Such scaling factors are constructed in piecewise linear fashion. This allows a compressed portion of the histogram to be spread out more than sparsely populated portion of the histogram.

Figure-3



Gray scale image and histogram before image enhancement-(Ref-Matlab-
understanding intensity value function)

Figure-4



Gray scale and histogram after histogram equalization (Ref-Matlab-understanding intensity value function)

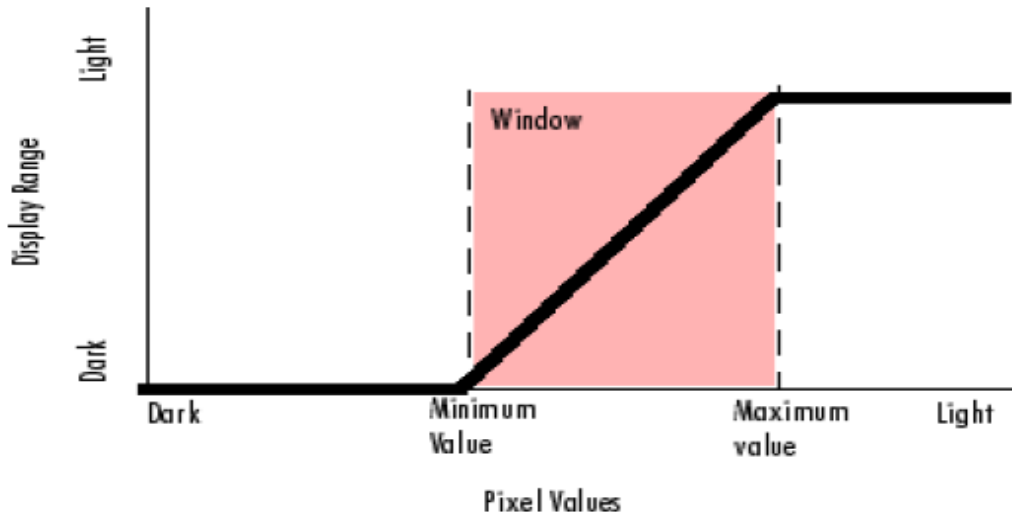
It is observed that before intensity adjustment the pixel intensity values were concentrated at a specific range as shown in the figure, after performing image enhancement it is visible that the image quality has improved and the pixel intensity values are not concentrated along a specific range, the pixel intensity values are spread throughout the entire gray scale range of [0-255], this improves the image quality.

Auto scaling is a special case of contrast enhancement where the pixel values below a specified value are displayed as black, pixel values above the specified value is displayed as white and the pixel values in between these two values are displayed as shades of gray. The result is a linear mapping of a subset

of pixel values to the entire range of grays, from black to white, producing an image of high contrast. The following figure shows this linear mapping.

Figure-5

Relationship of Pixel Values to Display Range



Relationship of pixel values to display range. (Ref- Matlab-Contrast stretching).

The gray scale values range from [0-255] these values while auto scaling is represented in a form of a percentage ranging 1% to 99%. Auto scaling as a function hardly fails to produce a high contrast image which makes extracting data of these images comparatively easier.

1.4 Histogram equalization.

Histogram equalization is a technique used to obtain an optimal contrast improvement by redistributing the pixel intensity values in order to produce a uniform histogram. An ideal output image of an histogram should have equal pixels at every intensity value on the gray scale. For an image with m rows and n columns using 1-bit gray scale resolution, the ideal histogram would be flat with $(m \times n/2^l)$ pixels at each gray scale value. Mathematically this can be shown as

$$N(g) = \max\{0, \text{round}\left(\frac{2^l \cdot c(g)}{m \cdot n}\right) - 1\}$$

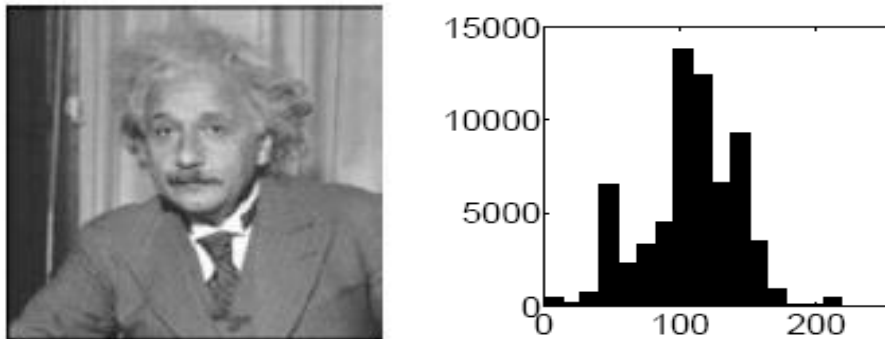
Where, $N(g)$ is the new gray scale value.

$C(g)$ is the cumulative pixel count up to the old gray level,

Round is used to round off the value to the closest integer value.

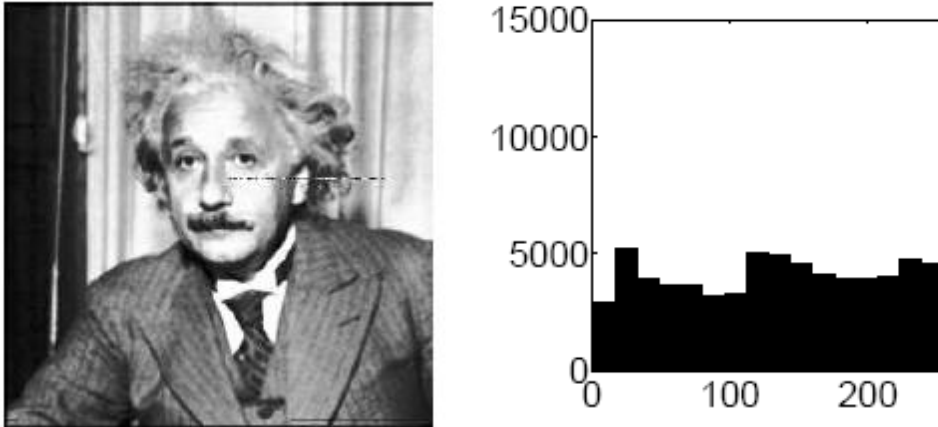
Histogram equalization is a very powerful tool, but it is not suitable for every image.

Figure-6



The figure above shows the gray scale image and histogram before histogram equalization. (Ref-fundamental of image processing-Hany-farid)

Figure-7



The figure above shows the gray scale image and histogram after histogram equalization. (Ref-fundamental of image processing-Hany-farid)

In this case it can be seen that using histogram equalization has created a better quality image by distributing the pixel throughout the gray scale value.

Histogram equalization works on a global level i.e. the entire image data is operated on this data also includes a lot of noise, an alternative which is used is adaptive histogram equalization, adaptive histogram equalization operates on small regions of the image known as tiles. Each tile's contrast is enhanced so that the histogram of the output region approximately matches a specified histogram. The data from the tiles are then combined using bilinear interpolation. An example of an histogram equalization is shown below.

Figure-8

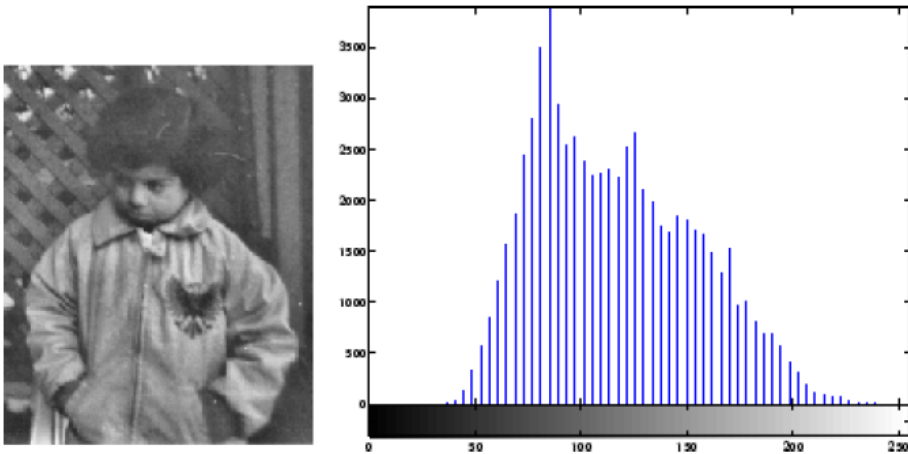


Image showing the adaptive histogram equalization-(Ref-Matlab-understanding intensity value function)

1.5 Remote sensing

Remote sensing was largely used in meteorology or military intelligence gathering and weather satellite imagery. Satellite imaging is widely used to monitor environmental data, US LANDSAT program has launched many satellites for imaging purpose. Applications of remote sensing are very vast.

In meteorology its used in application of short term weather forecasting. The data obtained from satellites are mainly used for long term weather forecasting such as global warming etc. Most of the data retrieved concerns the study of currents in ocean and fluxes of heat and water vapor in the ocean or atmospheric boundaries. From the data collected it is observed that thermal capacity of the whole atmosphere is mainly entered over the top five meters of the surface of water.

Image processing for the remote sensing data is performed by assigning a grey level to a pixel intensity value so that the sensed radiation can be visualized. Raw data usually in this form will require lot of preprocessing to enhance its application potential.

NASA's earth observation program offers satellite images for environmental monitoring. NASA offers image analysis software tied up with the Google earth, the satellite images are full color JPG files offering oceanic, atmospheric, energy, land and life data.

The oceanic data shows the average sea surface temperature, snow cover and sea ice extent water level radiance etc. Images below show the oceanic image data.

Figure-9

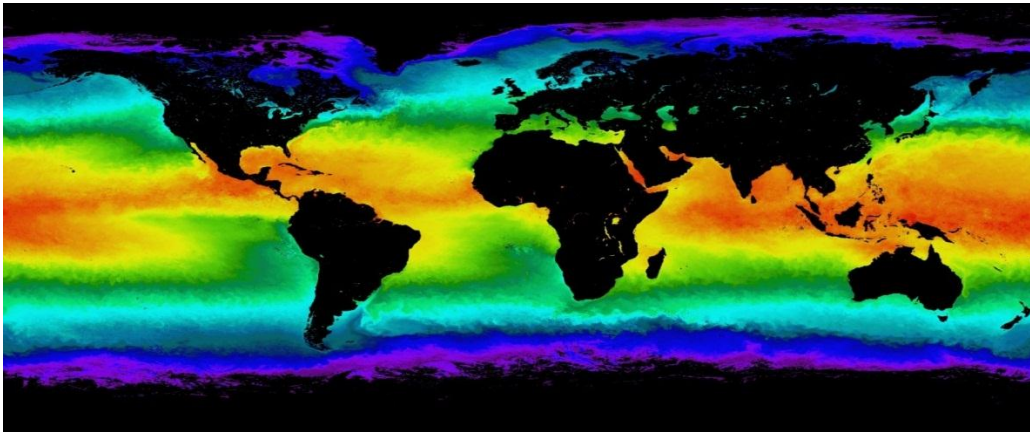


Image shows the average sea temperature data (Ref-NASA-NEO).

Figure-10

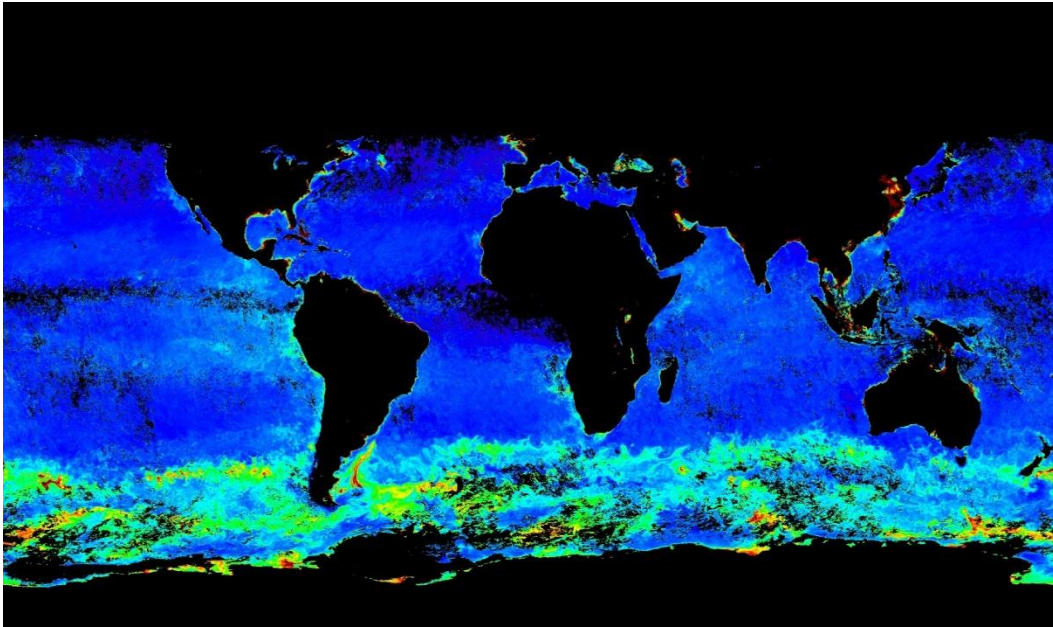


Image shows the water leaving radiance data (Ref-NASA-NEO).

The atmospheric image data includes cloud fraction, carbon monoxide, water vapor rainfall etc. some of the image data is shown below.

Figure-11

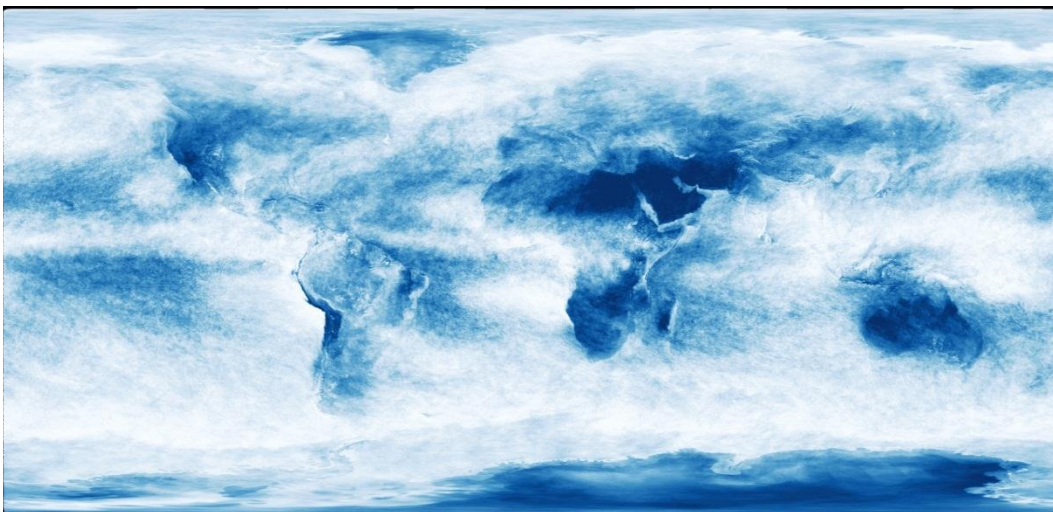


Image shows the cloud fraction data for a month. (Ref-NASA-NEO).

Figure-12

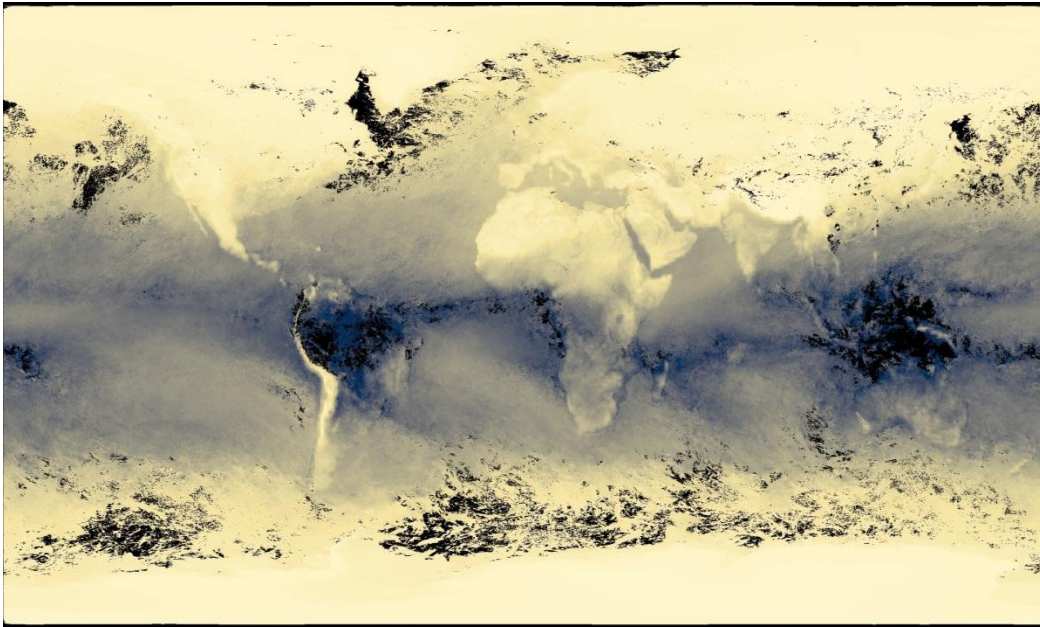


Image shows the water vapor data for a month. (Ref-NASA-NEO).

Figure-13.

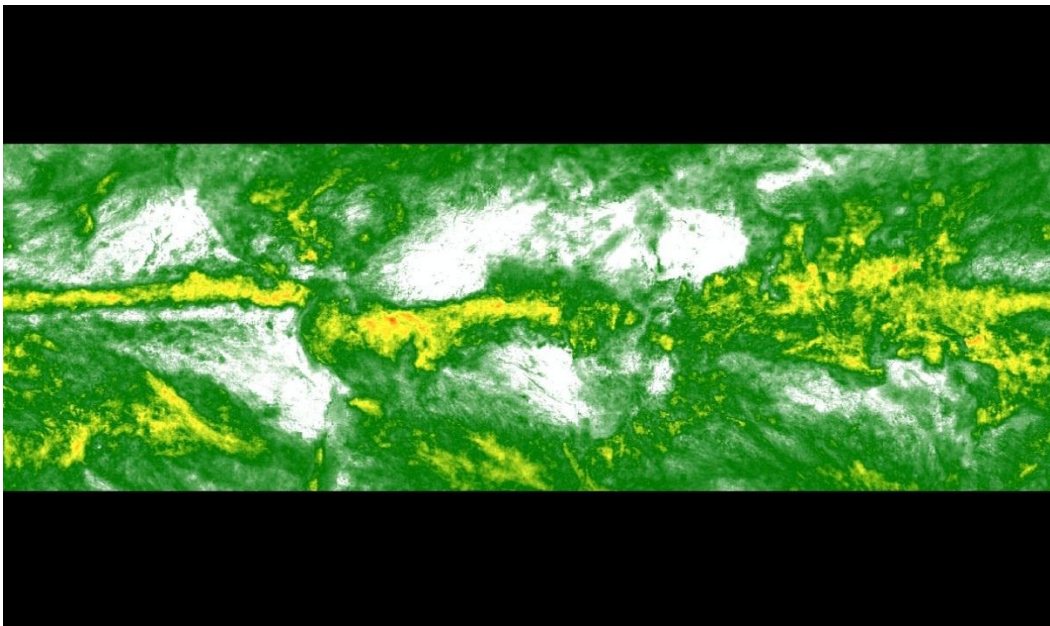


Image shows the total rainfall data for a month. (Ref-NASA-NEO)

Images above can be interpreted to show climate change, global warming and other information which helps predicting the weather.

Image processing has a very diverse application ranging from industrial application to environmental monitoring. The document shows image processing used in environmental monitoring and medical application involving micro channels to monitor and observe the flow of fluids.

Chapter 2

EXPERIMENTAL SETUP AND PROCEDURE USED FOR IMAGE PROCESSING IN ENVIRONMENTAL MONITORING.

2.1 Image processing in environmental monitoring.

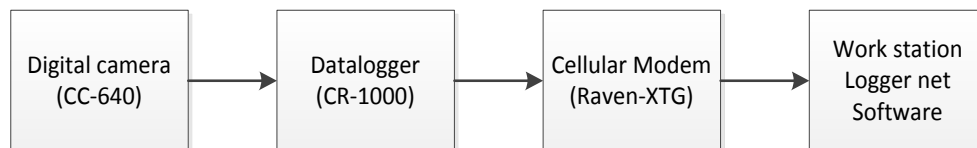
The image processing done in the project below is on a canal at Indian bend. Where there is a perennial flow of water. There has been a scale mounted on the canal to determine the level of water. Image processing is applied to obtain the above data and monitor the flow of water throughout the day. The images are captured at 15 minute intervals starting from 7:00 AM to 7:00 PM.

The images in our case which is the data source is obtained using a digital camera CC640 provided by Campbell Scientific, a data logger CR1000 and the captured images are being transferred using a cellular modem RAVEN XTG which works with AT&T network using a high speed data connection to transfer the images to a work station remotely. The images are received on the workstation which is configured with advanced image retrieval software known as Logger Net which is also provided by Campbell scientific.

2.2 Experimental Setup

The image capturing method and transfer is described below.

Figure-14



1. Digital camera CC640.

2. Data logger CR1000.
3. Cellular Modem RAVEN XTG.
4. PC Software Logger Net.

The connection between the equipment's is briefly described below

The digital camera is used to capture the image the image is stored on to the Data logger which has a 4 MB storage capacity the image captured from the Digital camera is transferred to the data logger using a CS I/O port from the camera to the data logger. The stored images are then transferred to the work station using a cellular modem the connection between the data logger and the cellular modem is established using the RS232 port. The logger net software installed on the work station uses an existing internet connection to connect to the cellular modem and to retrieve the images. A detailed description on configuring the equipment's used is given in the following section.

2.3 Device configuration.

The devices used had to be individually configured before the connection could be established the detailed description of configuring the device is given below.

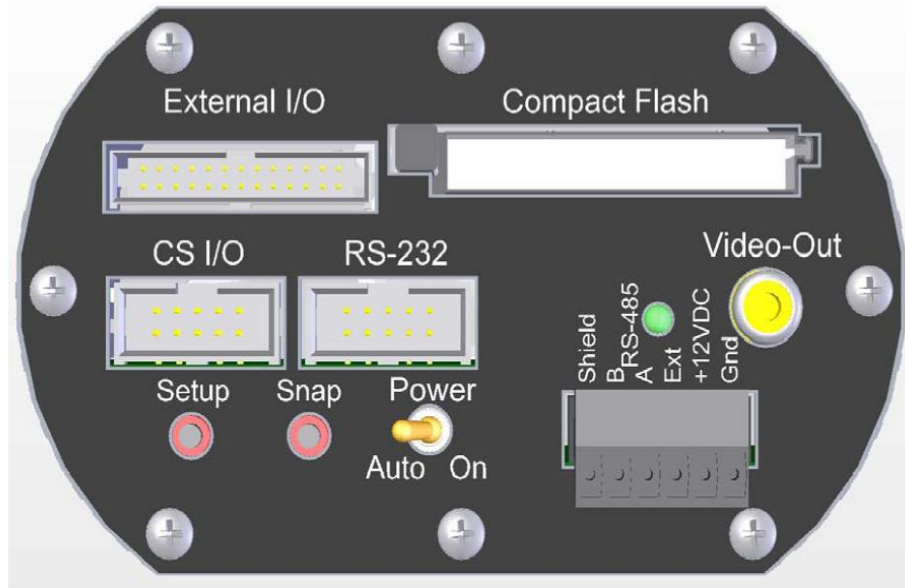
1. Digital Camera CC640.

The CC640 digital camera is a rugged camera as it can operate over a wide temperature range, it is also very low on power consumption that makes it suitable for use in remote battery powered operations.

The digital camera can be used to capture images using the installed snap button on the back of the camera or in standalone operation where the camera can

be configured to capture images in specified intervals over a period of time during the day. In the standalone operation mode the camera wakes itself up from hibernate mode to capture the image and goes back into hibernation once the image is captured.

Figure-15.



The camera hardware (Ref-Campbell scientific-CC640 User manual)

1. External I/O: The external I/O port is used to operate the camera peripherals such as capturing an image.
2. Compact flash: The compact flash port can be used to install a compact flash memory card which can be used to images. The camera has a very high image compression making it possible to store up to 10,000 images.
3. CS I/O and RS232 connections: These ports on the camera are used for communication and configuration. The CS I/O and RS 232 ports is used in

combination with a DB9 cable to establish a connection to the computer or the data logger.

4. Power switch: This switch is used to power the camera continuously on or in auto power mode. The camera should be place in auto mode when being used by an external trigger or in self-timed mode, as in auto mode the camera is put into a low power quiescent mode of operation.
5. Setup button: Pressing the setup bottom performs two functions, firstly it toggles the video output on or off and secondly the camera's RS232 port is opened for communication with the computer to setup the camera which is done using the device configuration utility software on the PC.
6. Snap button: This button is used to manually capture the image the camera needs to be in on position to perform this function.
7. Terminal block connection.

Table-1

Gnd	Power ground
+12VDC	9-15VDC power, 250 mA
Ext	External trigger input, 5.0 Volt signal.
RS-485A	RS-485 communication
RS-485B	RS-485 communication
Shield	Drain wire

The digital camera's settings are configured by connecting it to the computer using RS232 port on the camera. The settings are edited using the

device configuration utility. The camera's baud rate is set at 115.2k and a connection is established between the camera and the computer through the serial port, the device configuration utility is used to set the clock, PakBus address and other operating parameters given in the table below.

Table-2

Parameter	Description	Default value
PakBus Port	None, CS I/O, RS232, RS 485. PakBus port Is used for communication between the datalogger to transfer the images	None
PakBus address	Options 1-4094, A PakBus address is assigned to the camera for PakBus communications	55
PakBus destination address	Option 1-4094. This is the PakBus address of the destination device where the image files are transmitted to.	1
Compression Level	Options: Very high, high, medium, low, none. This option selects the amount of compression to be applied to JPG files. Higher compression level implies smaller file size with loss of subtle details in the image.	High
Start minute	0-1339 minutes. The option is used in self-timed mode to set the start time of image capture.	0
Stop minute	0-1440 minutes.	1440

	The option is used in self-timed mode to set the stop time of image capture.	
Self-timed interval	0-1440 minutes. This parameter is used to wake the camera in equal time interval to capture the image.	0
Fixed file name	On, off. This option helps assign a file name for the images captured.	
Time stamp	Options: off, bottom, top, Inside top. A date and time stamp will be placed on the images captured.	Off
Clock	The Date and time on the camera is set to the current time.	N/A

Lens

The default lens on the CC640 is a CS mount lens manual focus. The lens is focused using the setup function where the camera's video output is enabled.

As per the site requirements an alternate lens was used with higher zoom capability the lens used was a 5-100mm manual iris zoom CS mount lens.

Camera operation

The camera is connected to a suitable power source and powered on using the switch, once the power is on the setup button is activated and the region of interest is focused using portable monitor and the video out port. Once the region of interest is in focus the camera is put on to the auto mode where it has been

programmed to capture images in self-timed interval. All the captured images are transferred to the data logger using the CS I/O port.

2. Data logger CR1000.

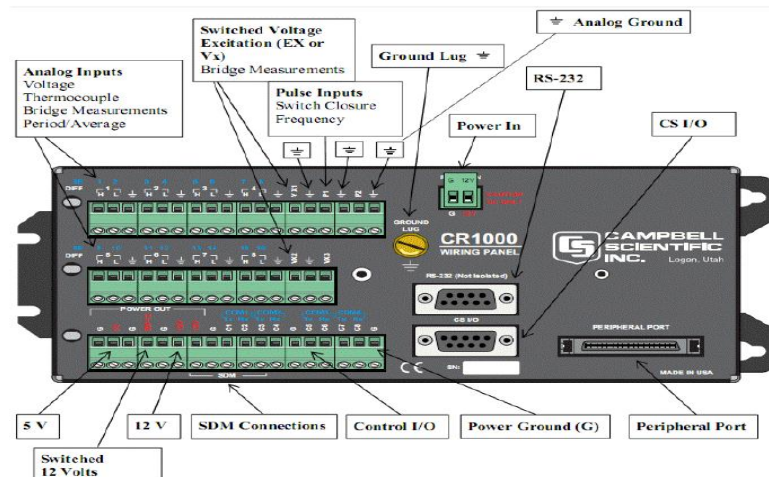
Introduction.

The data logger used in this project is the Campbell scientific CR1000 data logger, the function and operations of the CR1000 data logger is very vast it is used in both analog and digital measurements, it is used in various fields such as weather monitoring, Image capture and communication, agricultural and industrial fields.

The data logger is a PakBus Data logger which use back bus communication to communicate between the camera, other data loggers or the PC. The configuration of the data logger is described below.

The hardware of data logger is shown in the image below.

Figure-16



Hardware configuration of CR1000 Data logger (Ref-Campbell scientific- CR1000 User manual)

1. Power in/ Power out.
2. RS 232 port.
3. CS I/O port.
4. Peripheral port.

These ports and peripherals are the most important in the operation of the project.

Device configuration:

The CR1000 data logger is configured using the device configuration utility software. The data logger is connected to a suitable power source and turned on, the data logger is connected to the PC using the RS 232 port on the data logger and a serial port on the PC this connection is established using a DB9 serial cable. Once the connections are made between the data logger and the PC the device configuration utility software is used to enter the settings window of the data logger. The configuration of the CR1000 is described below.

The settings of the datalogger are edited under the deployment tab on the settings window,

1. Datalogger setting: This window shows the datalogger information, such as the serial number, station number, the operating system running and the PakBus address which is 1, this is the PakBus address that is assigned same as the destination PakBus address assigned in the CC640 digital camera, this PakBus address is where the communications are operated.
2. Comport Settings: comport settings are assigned to establish connection between the datalogger, the comport is assigned to RS-232 port, the default baud rate when establishing a direct connection to the PC is assigned as 115.2K.

3. TCP/IP settings: TCP/IP settings are network protocols which are used to establish connection between computers or internet devices. The TCP/IP setting on the CR1000 are as shown below.

IP address- 0.0.0.0

Subnet mask- 255.255.255.0

Default gateway- 0.0.0.0

DNS server1- 0.0.0.0

DNS server2- 0.0.0.0

By assigning all the values to zero, the data logger takes the IP address assigned by the router on the communications modem connected to the datalogger.

4. Advanced settings: In this settings window the virtual drive is created on the datalogger where all the data files are stored, the format of the files saved is also defined such as JPG or any other desired file format. The settings defined are shown below.

Is router – No.

SDC Baud rate: 57.6K fixed. This is the baud rate where the images are transferred to and from the datalogger.

USR Drive size: 259072 bytes. This is the allocated size of the virtual drive where the images are stored.

Table-3

Files manager file name.	PakBus Address	Files manager count
USR:test1.jpg	55	4

The files manager is where the directory, file name and the PakBus address is defined it is as shown in the table above. The images are stored on the USR drive named as test1 in the JPG format, the image number increase sequentially, PakBus address is the address where the data is received from in this case it is 55 which is the PakBus address of the CC640 digital camera. A maximum of 4 files are saved on the datalogger at one time before it is erased and overwrite by the new data files.

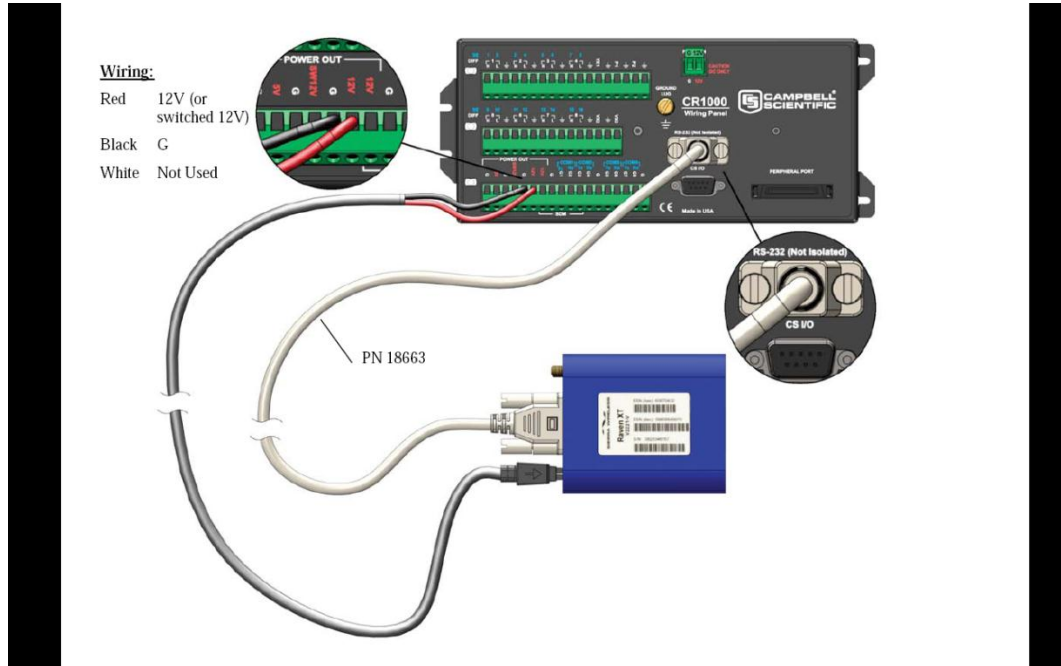
Once the settings are adjusted it is applied to the datalogger and disconnected. The configuration is tested by connecting the camera and the datalogger to a suitable power source and connecting the camera to the CR100 datalogger over the CS I/O port. The images are captured manually on the digital camera and the datalogger is connected to the logger net software using a direct comport connection and the data files saved on the USR drive is verified.

3. Cellular modem Raven XTG

The raven XTG cellular modem is used to establish a connection between the data logger and the logger net software. The cellular modem works on data service provided by the wireless service. To establish a connection with the cellular modem a static IP was assigned to the device. This static IP provides an address to establish a communication signal over the Static IP.

The cellular modem was connected to the CR1000 data logger on the RS 232 port the connection is shown in the figure below.

Figure-17



Connection between Datalogger and cellular modem-(Ref- Campbell scientific- Raven XTG user manual)

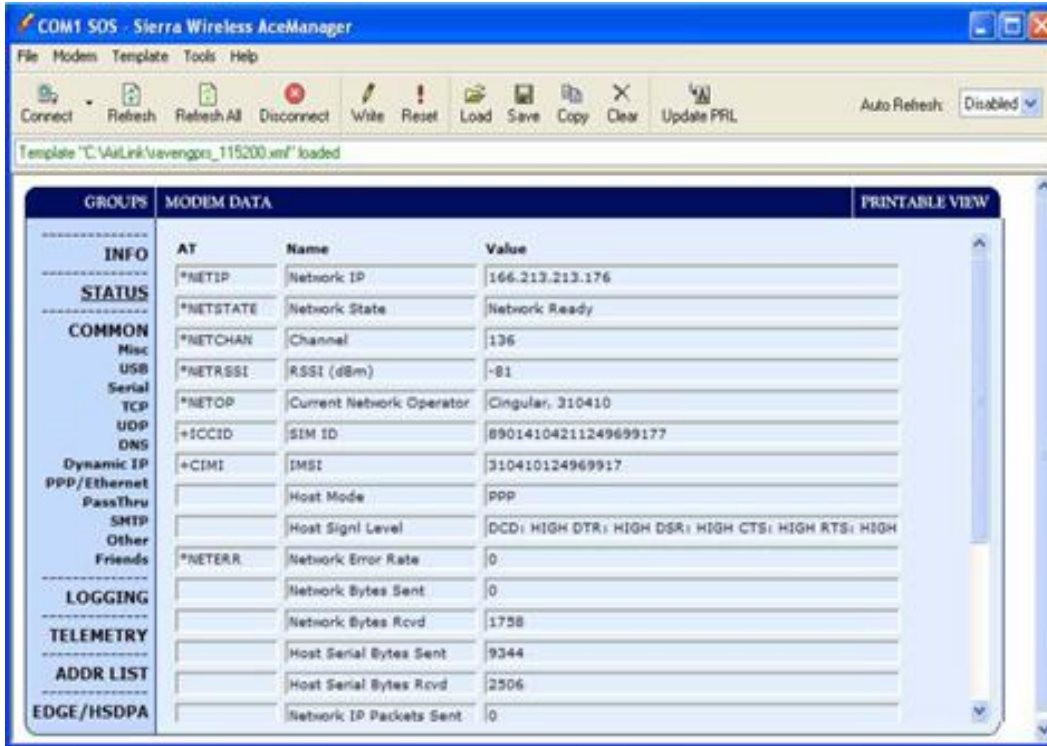
The Cellular modem is connected to the power source on the data logger. The communication between the cellular modem and the CR1000 data logger was established using a null modem cable this is a 9 pin cable on both the ends and a directional antenna was connected to the cellular modem to transmit signals. The cellular modem was configured using the ACE manager software, the configuration is described below.

The cellular modem is powered using a suitable power source, the antenna is connected. The cellular modem is connected to the PC using the direct RS232 cable. Once the connection is established run the ACE manager software.

On the connect screen the 'PPP' mode is selected and the appropriate com port to where the cellular modem is connected. Once the setup mode is entered a suitable template file for compatible data loggers is loaded. The template file configures the modem to the Campbell scientific Data logger in this case the CR1000.

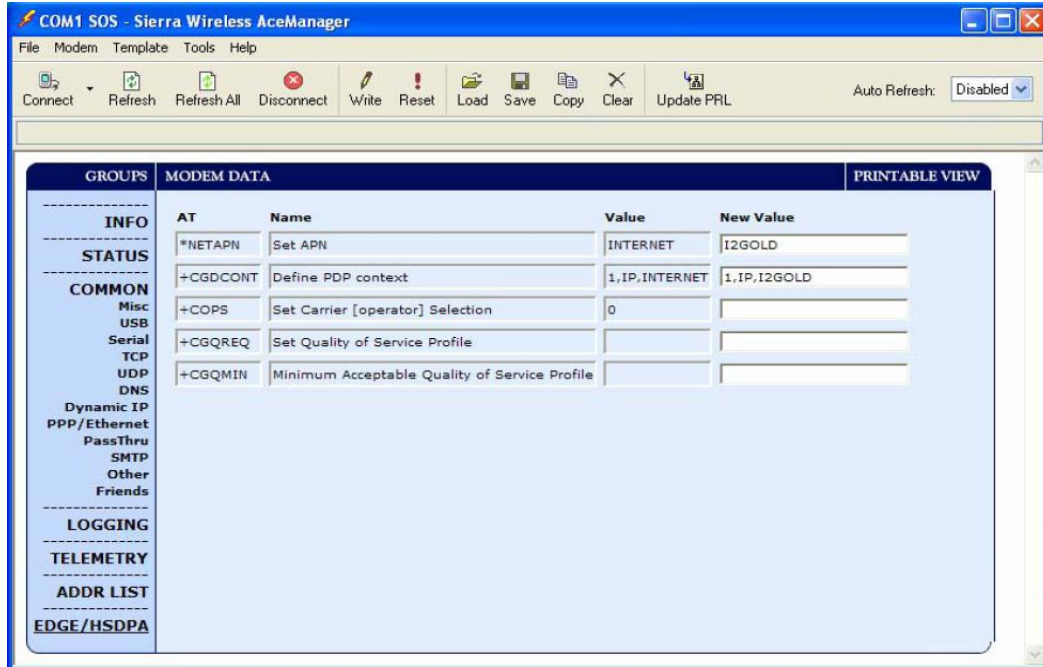
Once the template file is loaded the static IP and APN provided by the wireless service provider is configured in to the modem. This is done by clicking on the TCP and EDGE/HSDPA tab on the setup screen. This setup screen is shown below.

Figure-18



Static IP configuration (Ref-ACE manager software Seirra wireless link modem)

Figure-19



APN configuration (Ref-ACE manager software Seirra wireless link modem)

Once the Static IP is entered on the settings page is entered the write button is clicked once the template file is loaded, Then the EDGE/HSDPA button is clicked, on this page the APN is entered once this is done the write button is clicked after making sure the template file is loaded. After the settings are entered the modem is reset, the modem is disconnected by clicking the disconnect icon to terminate all the connections with the modem. Once the modem is configured and connected to the data logger, the logger net software needs to be configured to establish a remote connection to the data logger to download the images. The configuration of the data logger is explained in the next section.

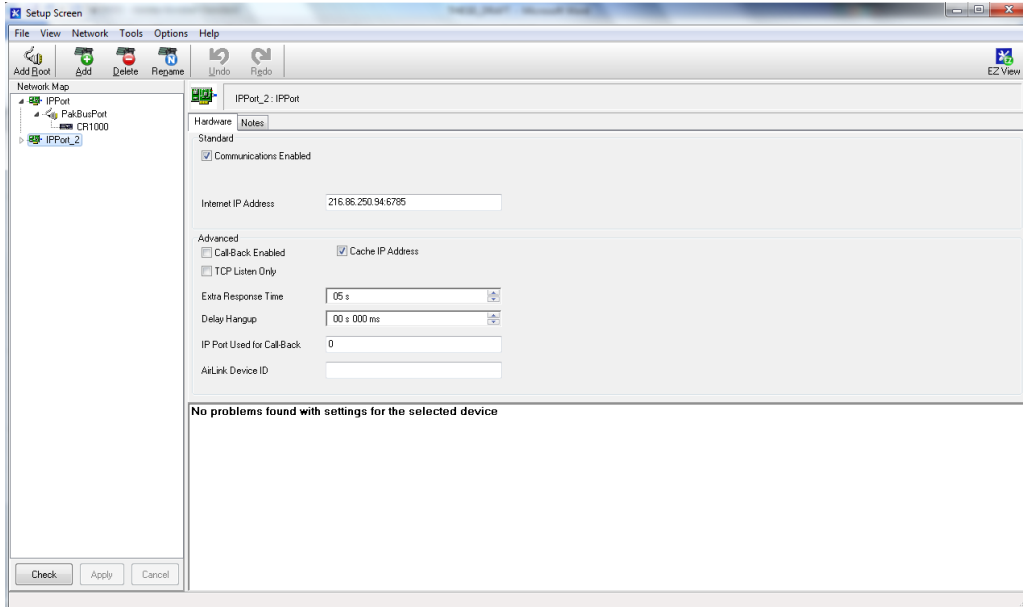
4. Logger Net – Data (image) retrieval software.

The logger net software is used to communicate with the data logger CR1000 over the cellular modem Raven XTG. The Device map is configured using the setup button on the logger net software. Once the setup mode is entered the following steps are used to configure the device map.

1. Add root and this select IP port.
2. Add a data logger to the IP port. In this case PakBus datalogger is added since the CR1000 is a PakBus datalogger.
3. On the IP port page we enter the static IP address and the port number. The Static IP address and the port number is entered in the following template “XXX.XXX.XXX.XXX:YYYY”, where XXX.XXX.XXX.XXX is the static IP address and “YYYY” is the port number. The extra response time on this page is set to 4 seconds.
4. The settings on the PakBus port are kept to default.
5. The data logger CR1000 is configured. As described. The PakBus address on this page is changed to the PakBus address assigned to the datalogger. In this case the PakBus address is changed to 1.

The device map configured is shown in the Image below.

Figure-20.



Logger net-IP configuration (Ref-campbell scientific logger net 4.0)

The settings mentioned above will establish a connection with the Datalogger for setting up Image retrieval the following setting are changed in logger net under the CR1000 datalogger which are described below. Under the CR1000 settings there are subcategories.

1. Hardware: In this tab only the Pak bus address of the Data logger is assigned to 1.
2. Schedule: The data collection schedule of the data logger is configured in this tab. The schedule collection enabled is checked, The Date and time of the Base station is set. The collection interval is set as desired in this case it is set to 15 minutes. Primary interval is set in case there is a failure in establishing a connection with the Datalogger it is set to 2 minutes.

3. Image files: In this tab the retrieval mode is set to “follow scheduled data collection”. In the file pattern window select add new, this adds a JPG file type. This sets the logger net to automatically transfer the JPG files on the datalogger. The Output directory is assigned as desired. This is the directory where all the retrieved images are going to be stored on the workstation. Once the settings are configured click on apply and the settings are saved.

4. Image retrieval: The Camera, datalogger and the cellular modem is connected to a suitable

Power source and the connections are made as described earlier. To retrieve the images the logger net software is opened and the connect icon is clicked, on this screen the datalogger to be connected is selected and the connect icon is clicked. Once the connection is established the images can be retrieved manually if desired, or the images will be retrieved as per the scheduled program and store the images in the directory specified. To retrieve images manually the file control icon is clicked and in this window select the 'USR' drive, this is the virtual drive created on the CR1000 to store data. The images to be retrieved are selected and the retrieve icon is clicked once the images are retrieved the window is closed. The connection to the datalogger is kept active for the software to retrieve images automatically as per the collection schedule. The images are captured is processed to determine the level of water in the canal using advanced image processing tools and software. This is described in the next section.

2.4 Experimental Procedure.

The purpose of this project is to obtain the level of water from the image retrieved by advanced image analysis. The device is configured as described before. The camera is connected to the datalogger using the CS I/O port and the cellular modem is connected to the datalogger over the RS232 port. The devices are connected to a suitable power source. The logger net software is turned on and a connection to the datalogger is established over the internet. The images are captured from 7 AM to 7 PM, with a 15-minute interval. All the image data is stored in the specified directory. The images are now analyzed and processed.

The images are captured in full color, the resolution of the image is 640X504. An image retrieved is shown below.

Figure-21



The scale on the image is of 2 ft. The scale is used as a comparison for the level of water to the level of water obtained by using image processing on the software.

The images retrieved are processed using MATLAB software, MATLAB has many advanced image processing tools. The detailed analysis used for obtaining the result is described below.

The image is initially read to the MATLAB software in this stage the image data is a full color RGB format. The image is then converted to a gray scale image. Doing this reduces the noise in the image and simplifies the process of analyzing the image. Once the image is converted to gray scale we have intensity range varying from only 0 to 255. The gray scale image is as shown below.

Figure-22



Once the image is converted to gray scale the region of interest is selected using the 'imtool' function in MATLAB. As the image contains lot of unwanted data

the image is cropped to the region of interest i.e. around the scale on the image. The pixels are chosen suitable to crop the image. The ‘imcrop’ function in MATLAB is used to perform this. The format of imcrop goes as specified ”
imcrop(I, [xmin ymin width height])” , the xmin and ymin are defined using the spatial coordinates on the image. The xmin is the low coordinate on the x direction or the horizontal axis and ymin is the lower coordinate value on the y axis or the vertical axis, the width and the height are the dimensions of the rectangle, this defines the crop dimensions on the image. The cropped image is as shown below.

Figure-23



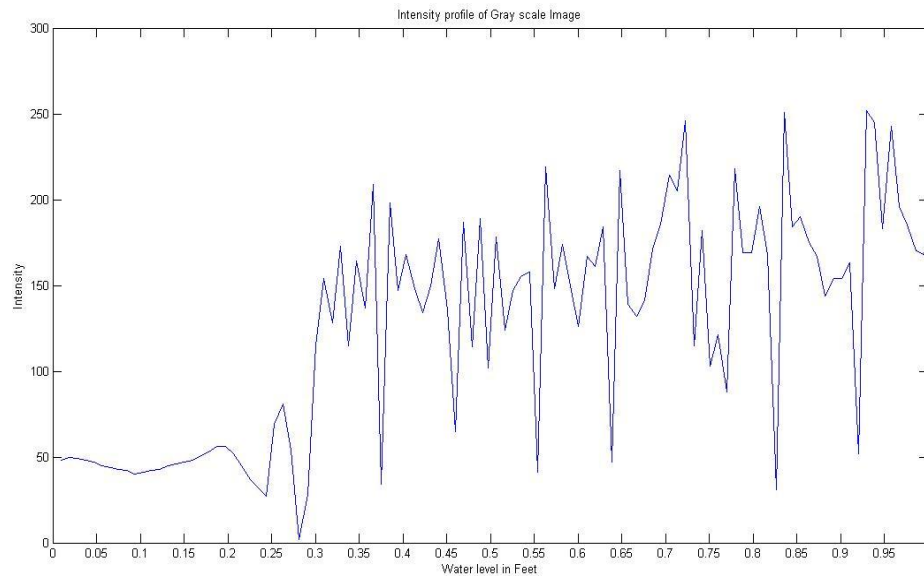
The crop is chosen such that ymin coincides on the 2ft marking on the scale, this makes the two feet mark as the 1st pixel. The dimensions of the rectangle are [110width x 214height]. Since the camera is fixed in a location the coordinates or dimension of the crop do not change. If the camera is shifted from

the original position the properties such as the xmin, ymin, width and height of the rectangle are reset using the imtool function.

The cropped image is now the data where the level of water is determined from. Since the image data is in gray scale each pixel intensity value varies from 0 to 255, these intensity values are used to plot an intensity profile along a specified vector from the first pixel on the image to the last pixel on the image height wise.

The pixel intensity profile along a vector defined along the scale is as observed in the image below.

Figure-24.



Pixel intensity profile of gray scale image.

As observed in the image the horizontal axis of the image represents the water level in feet, the pixel intensity is plotted for data between 0 to 1 ft. on the scale of the image for simplicity of the plot. The vertical axis represents the Pixel intensity value which varies from 0 to 255. The plot reveals that the intensity of

the water and the background scale does not mark an evident difference. The intensity plot represents a lot of noise. This noise or fluctuation in the pixel intensity values are reduced by adjusting the contrast of the image, this is done by using contrast stretching property.

The contrast of the image is adjusted using the “imadjust” function in MATLAB. The format of the imadjust tool is

```
K = imadjust(I,[Low in; High in],[low out; high out]);
```

K is the output image after the contrast has been adjusted.

Imadjust is the function that varies the contrast.

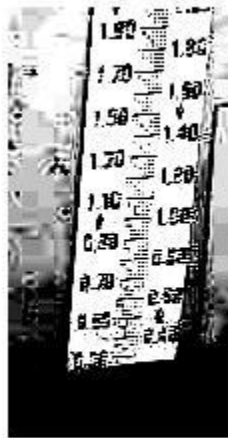
I – this is the Image data for which the contrast has to be altered. In this case it is the cropped gray scale image.

[Low in; High in]- These are the low and high input intensity values to be entered, these values ranges from 0 to 1.

[Low out; High out]- These are the output intensity values to be entered, these values ranges from 0 to 1. The low out and high out values does not imply to this particular case as the image data is gray scale image, hence these values are left blank.

The image after applying the contrast adjust function is as shown below.

Figure-25



The function used in MATLAB for the gray scale image will be.

```
K = imadjust(I,[Low in; High in],[,]);
```

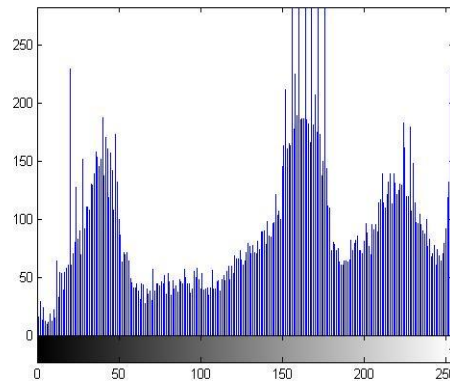
Initially the Low in and High in values were entered in manually using trial and error method. For the values to be chosen automatically a Curve fit model was used. The parameter used in the curve fit model is the Mean and Variance of the pixel intensity values. The image statistics such as the mean and variance of the pixel intensity values are obtained by analyzing the histogram of the gray scale image. The mean and variance of the gray scale images vary throughout the day, during the day time the mean and variance are found to be higher than the mean and variance observed later point of the day. The change is observed as the sun light is directly incident on the region of interest during the day and as the day progress the sunlight falls behind the scale creating a shadow

on the scale this reduces the mean and variance of the gray scale image.

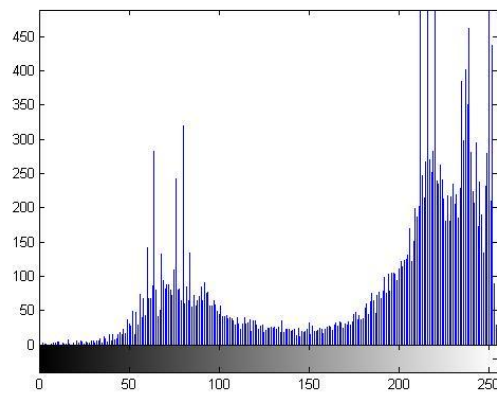
Histogram of the gray scale images as the day progresses are shown below.

Figure-26

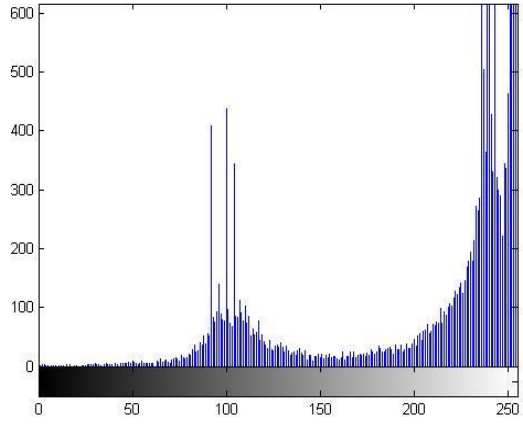
7:00 AM



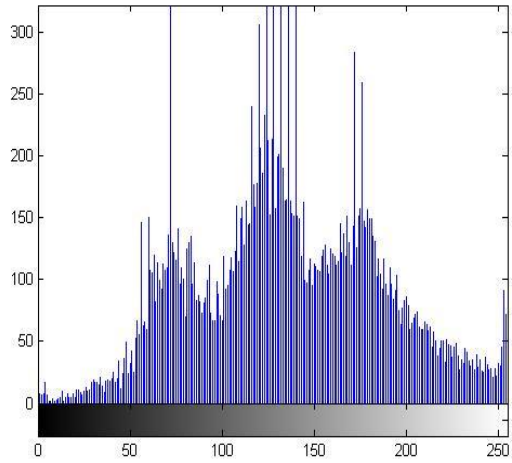
8:00 AM



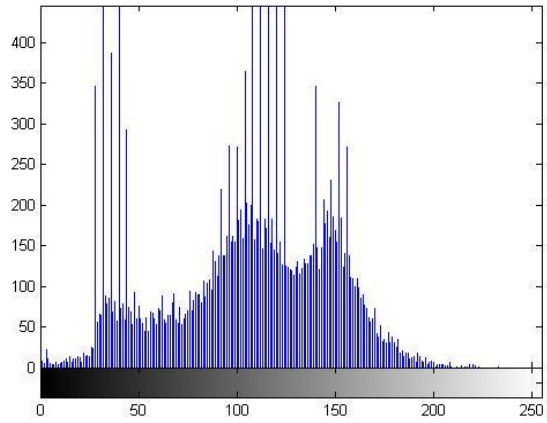
9:00 AM



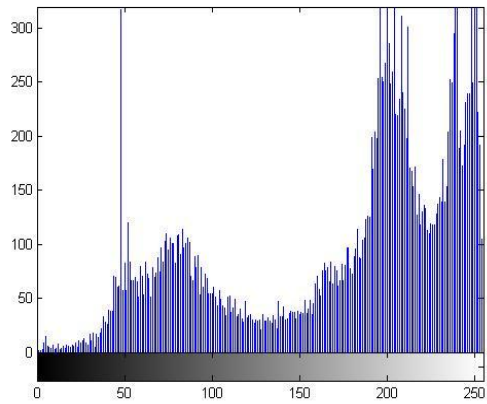
10:00 AM



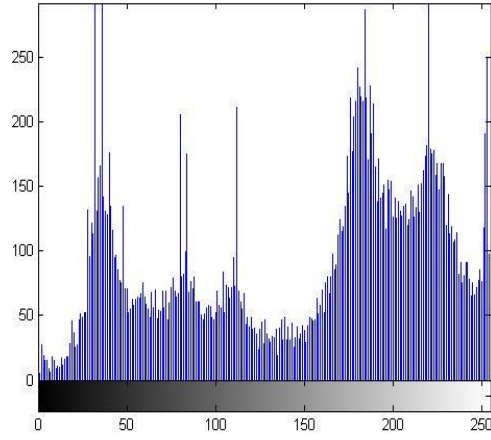
11:00 AM



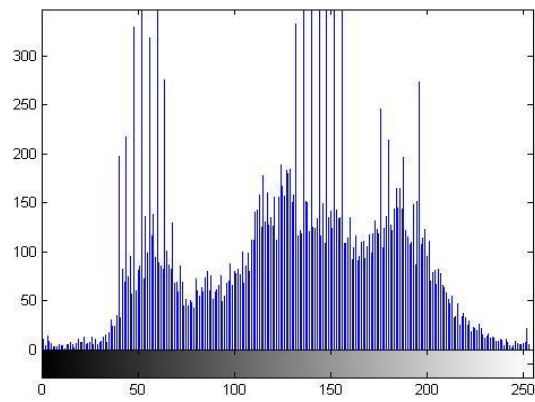
12:00 PM



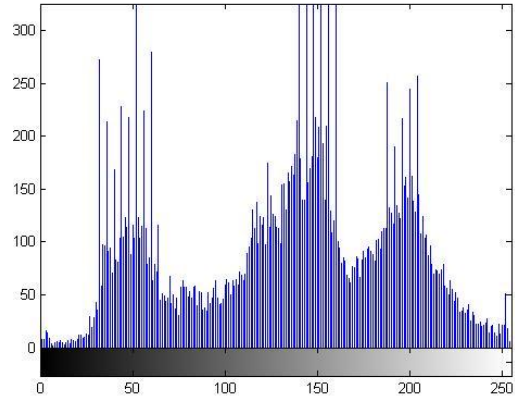
1:00 PM.



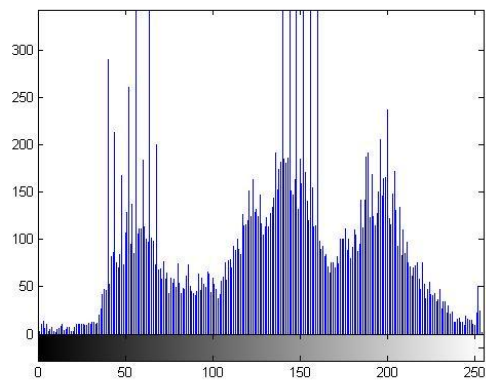
2:00 PM



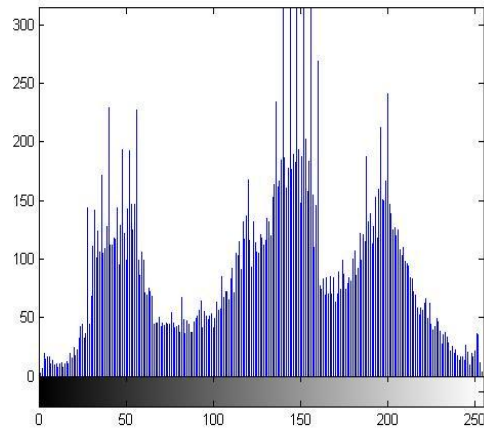
3:00 PM



4:00 PM



5:00 PM.



The above figure shows the images throughout the day and the histogram for the region of interest in gray scale. The mean and the variance for the day are tabulated below.

Table-4

Date	Time	Mean	Standard Deviation	Variance
Nov_3rd	7:00 AM	142.6401	70.437961	4961.506
	8:00 AM	187.87551	62.549844	3912.483
	9:00 AM	210.1801	56.637144	3207.766
	10:00 AM	135.65305	49.499134	2450.164
	11:00 AM	103.92973	41.432857	1716.682
	12:00 PM	174.42577	66.147232	4375.456
	1:00 PM	147.29126	73.122588	5346.913
	2:00 PM	130.37486	50.438268	2544.019
	3:00 PM	134.4665	57.281009	3281.114
	4:00 PM	135.62627	54.449669	2964.766
	5:00 PM	132.46231	58.379753	3408.196

Table: Histogram statistics.

The table above shows the histogram statistics of the gray scale image, The histogram plots the intensity against the no of bins, it is relevant from the plots that the mean and the variance are on the higher intensity values during the day and is on the lower intensity during the evening. There histogram statistics are affected during different weather conditions such as rainy days and cloudy days, the effect of weather on the intensity values are significant as the pixel intensity values are reduced during rainy and cloudy conditions.

The curve fit equation was obtained by collecting data over 10 days, the data included the histogram characteristics such as the mean, standard deviation , variance and the low in and high in values used in the 'imadjust' function of MATLAB, the low in and high in are obtained from trial and error for the entire period of data collected.

Algebra analysis is used to obtain the curve fit equations for the data collected. The curve fit equations for the low in and high in are as given below.

$$\text{Low in} = 0.003589*B - 4.022e-6*V;$$

$$\text{High in} = 0.004327436*B + 7.04752e-9*V$$

B – Mean obtained from the histogram data

V- Variance obtained from the histogram data.

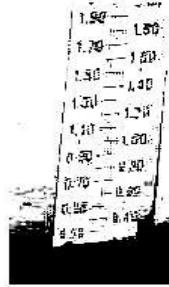
The above mentioned curve fit equations can be used to adjust the contrast of the image. The adjusted image using the curve fit equations are shown below.

Figure-27

7:00 AM



9:00 am



10:00 AM



1:00 PM

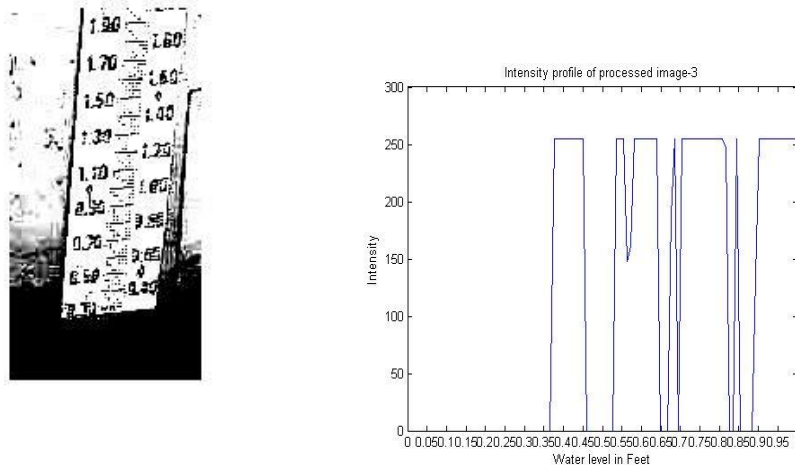


4:00 pm



The images show the contrast adjustments between the raw gray image and the contrast adjusted images. As it is clearly visible the level of water on the scale is very distinct, the background i.e. the scale is white and the water is black, this gives a very clear marking of where the level of the water is in comparison to the scale. Plotting the intensity profile of the image will clearly show the transition from water to the scale. The pixel intensity plot for the contrast adjusted image is as shown below.

Figure-28



The intensity values are plotted using specific vectors along the scale in the region of interest. The intensity values are plotted from the top of the scale to the bottom of the scale along the scale, the vector coordinates are selected using the 'imtool' function in MATLAB. There are some gray scale images with some noise around the water and the scale, this noise is generated due to the light conditions, at noon as the sun is directly above the water, it turns the water transparent hence adjusting the contrast would create some noise, image showing the noise are shown below.

Figure-29



Noisy image data captured at 1:15 pm.

As it is observed in the contrast adjusted image there is a lot of noise, hence to get an accurate result of water level, three vector coordinates are defined along the scale to obtain the level of water and the average of the water level is taken.

Figure-30



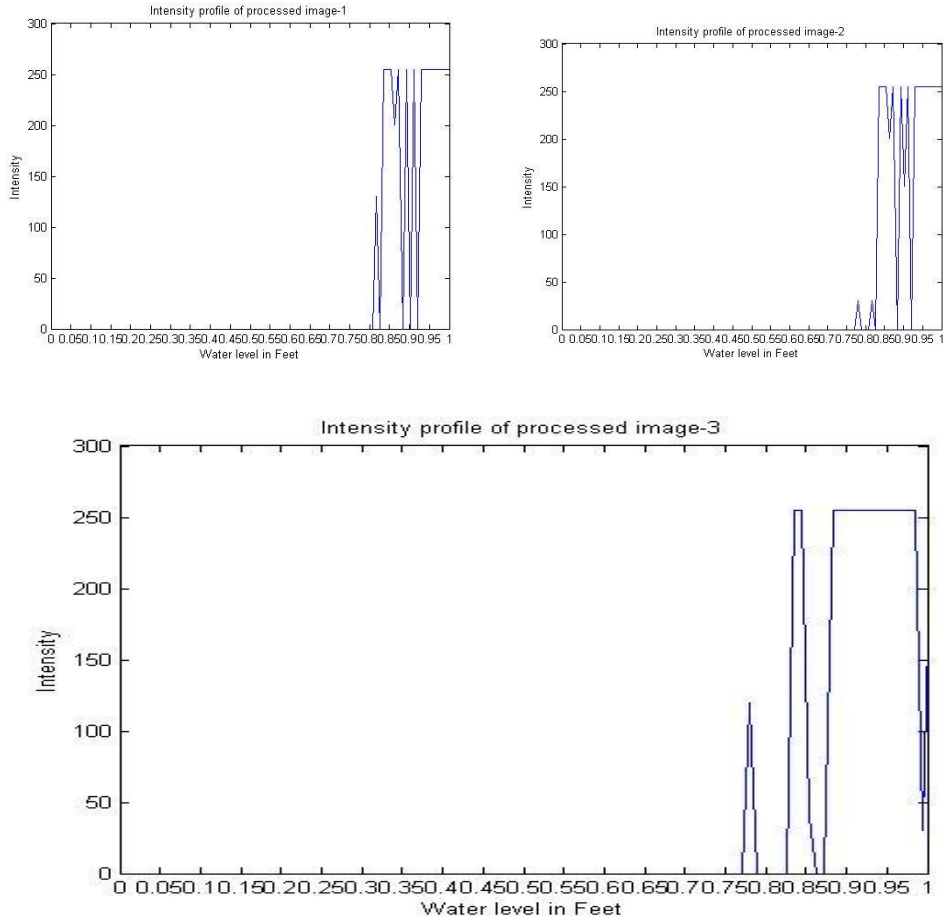


Fig: 1, 2, 3, 4, 5, 6- Raw image, gray scale image, Contrast adjusted image, Intensity plots.

The images above show the level of water plotted after the adjusting the contrast on the gray scale image. The raw image is cropped and converted to gray scale, the contrast of the gray scale image is adjusted using the ‘imadjust’ function once the contrast is adjusted pixel intensity values are plotted along the three vector coordinates this shown in the figures above.

The level of water is determined by analyzing the intensity plots, the logic applied in determining the water level from intensity plots goes as described, an equation is generated which counts the number of pixels which are of zero intensity if there

are 10 pixels or more of zero intensity in a sequence the first non-zero pixel before the zero is selected as the pixel where the level of water stands, since the pixel count is known the length of the scale is known which is 2 feet and the number of pixels taken for 2 feet is known, thus a conversion is made between the number of pixels and the length of the scale, 2 feet is equivalent 213 pixels, thus the length of 1 pixel is determined. This unit is used for the pixel number determined by the Level equation and the number of pixels with non-zero intensity values is converted to the level of water.

The images captured and retrieved from the canal are analyzed using MATLAB the results are tabulated and discussed in section 4.1.

Chapter 3

EXPERIMENTAL PROCEDURE AND SETUP USED FOR HIGH SPEED IMAGING ANALYSIS

3.1 High speed image analysis of fluid in a micro channel

This section describes the experimental procedure and results of high speed imaging and analysis of fluid flowing in micro channels. There were different kinds of presses used to manufacture the micro channels those include Ballistic press, hydraulic press, Laser press, Rotary and Stamped press, all these presses were tested with water based dye and whole milk to analyze the flow duration and flow pattern in the micro channel. The experimental setup and procedure is described in the next section.

3.2 Experimental setup

High speed digital camera is used to capture the video of the fluid flowing through the micro channel, the high speed digital camera is a Casio-Exilim FH25, this camera shoots high speed video at 1000 frames per second. The camera has different settings to capture images at different speeds 240fps, 420fps and 1000 fps. This experiment is conducted with videos being recorded at 420fps. The resolution of the video (224x168) shot at 420fps. There are two types of presses which are used in this experiment one is a single channel press and the other is a 3 channel press, the image of the channels are as shown in the images below.

Figure-31

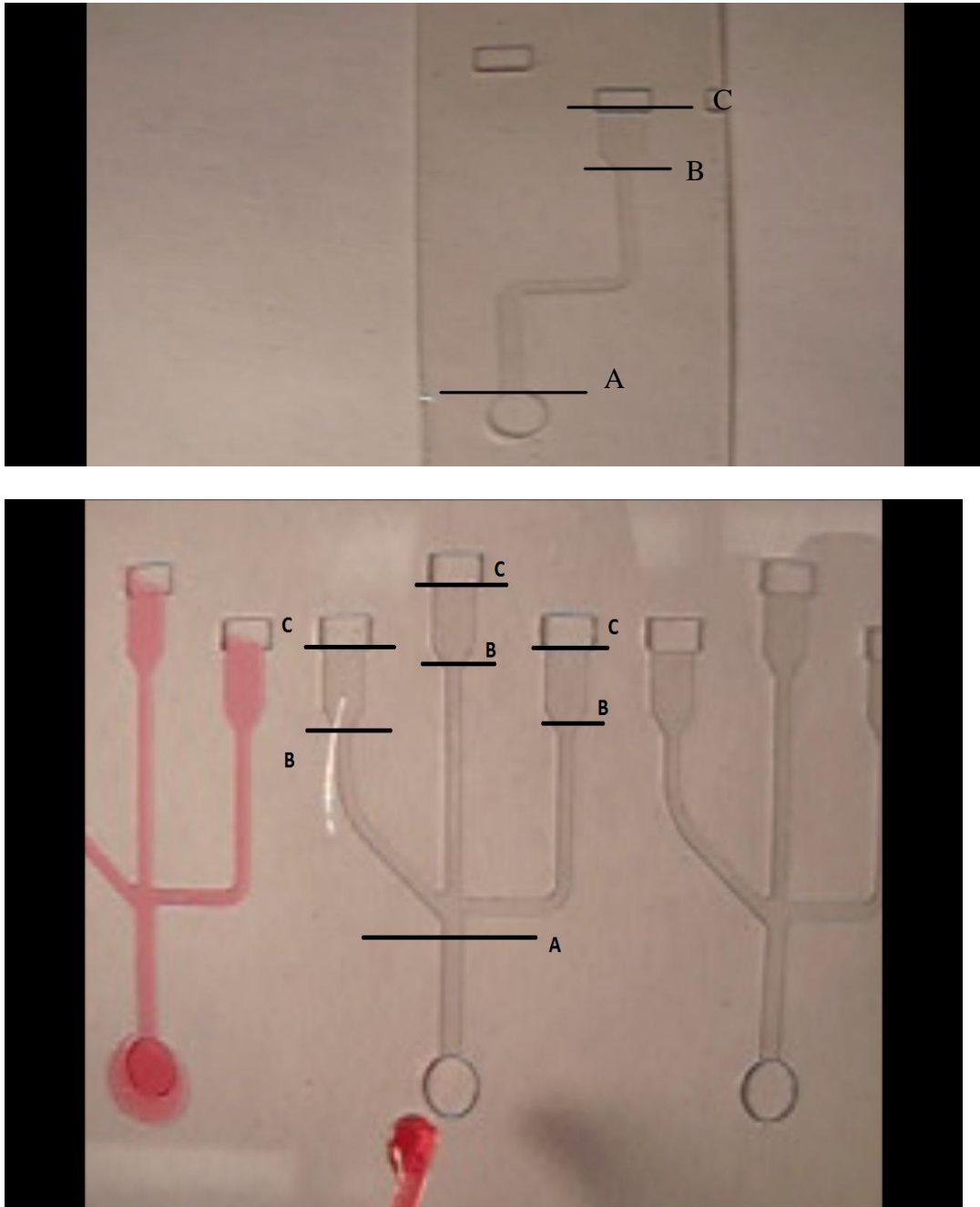
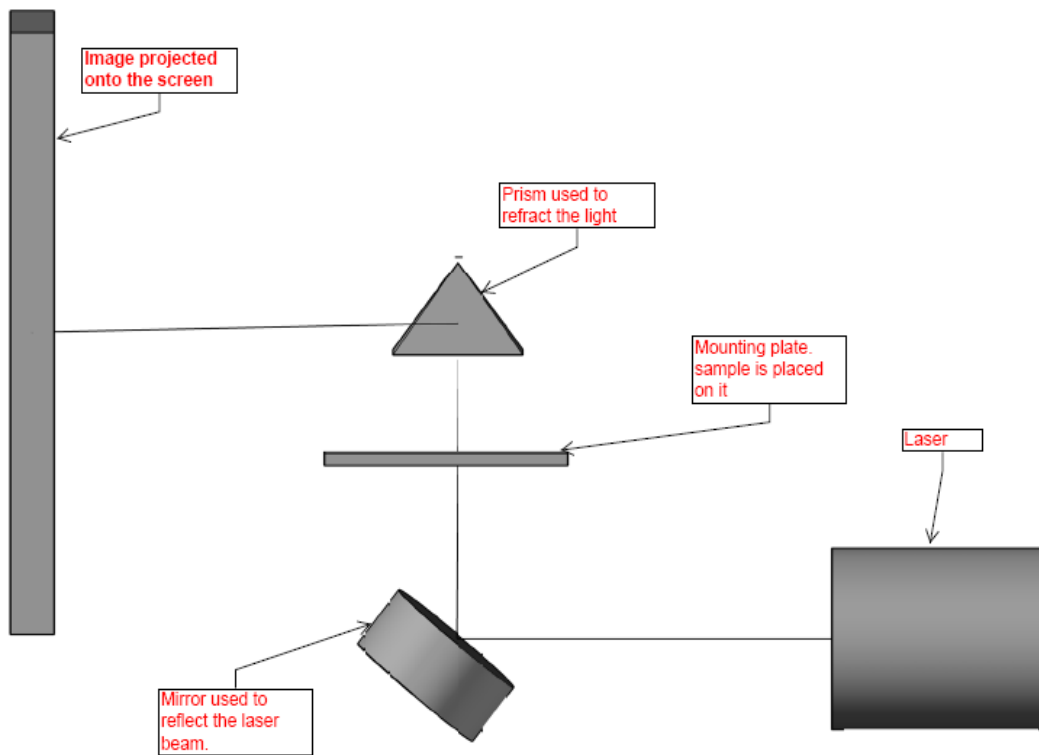


Fig: Single channel and 3 channel press representation.

The single channel press is of the rotary and stamped press, the flow duration is monitored for the entire channel (A-C) and the duration of flow for the reservoir (B-C),

The experiment is also conducted by exposing the channel to a beam of laser and projecting on to a screen. A high power laser is used to project the channel onto the screen. The 30 W laser is pointed at a mirror which reflects the beam on to the channel placed on a mounting plate the beam is then projected on to the screen using a triangular prism. The experimental setup is as shown in the image below.

Figure-32



Experimental setup for laser projection of samples. Image constructed in AUTOCAD-3d.

The channel is projected on the screen to observe and analyze the defect of fluid flowing in the channel.

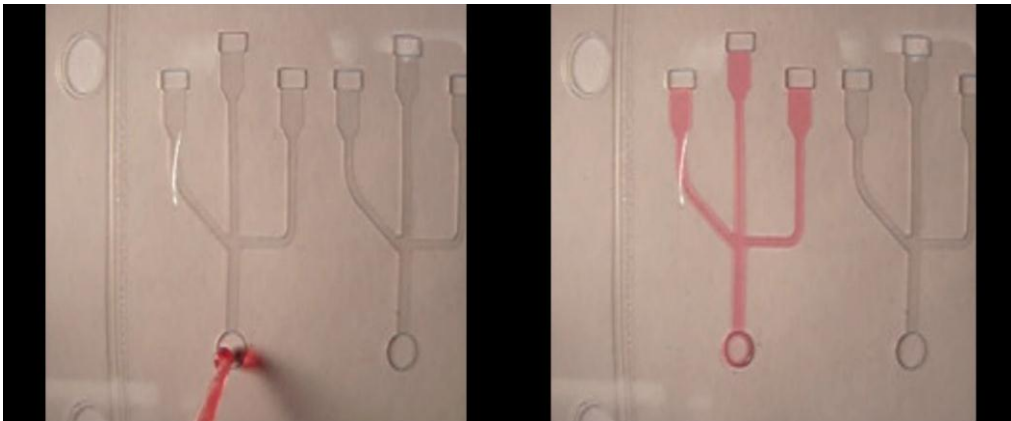
3.3 Experimental procedure

The sample press is placed on a white or red board to create a suitable from the water based red dye or with milk respectively. The camera is focused on to the channel it is made sure that there is channel is illuminated substantially.

The dye or milk is introduced into the channel using a pipette.

The flow is observed for any defects and the duration of flow is recorded. The images of channels with water based dye and whole milk is shown below

Figure-33



Shows a ballistic three channel with water based dye as the fluid. Images show before the fluid was introduced into the channel and after the flow is completed in the channel.

Figure-34



Fig: Shows a ballistic press three channel with whole milk as the fluid. Images show before the fluid was introduced into the channel and after the flow is completed in the channel.

Figure-35

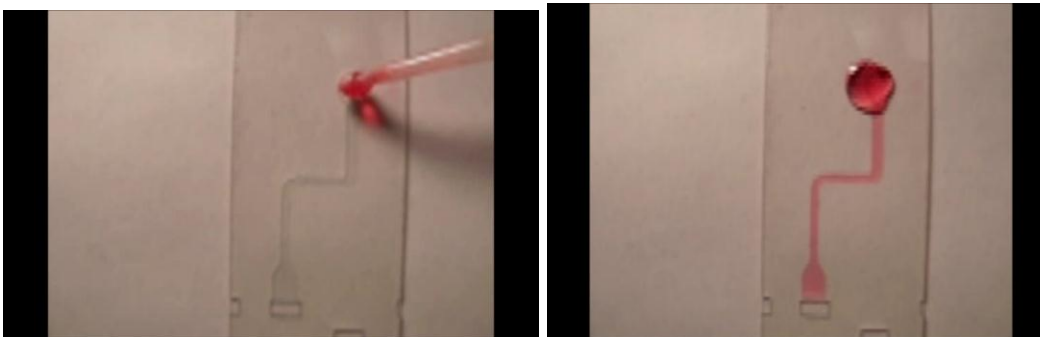


Fig: Rotary press single channel, with water based dye as fluid.

Figure-36



Fig: Rotary press single channel, with whole milk as fluid.

The experiment with water based dye as fluid is repeated for all the channels of Ballistic press, Hydraulic press and the Laser press. 30 samples of each of the types of presses are analyzed for the duration of flow for the entire channel (A-C) and the duration of flow for the reservoir (B-C). The results are tabulates and the Avergae, standard deviation and variance of the flow time are calcualted and discussed in the results section.

The experimental procedure for channels projected using laser beam is described below. The high power laser is connected to a power source and switched on, the set of channels is kept on the mounting plate. The lights in the Laboratory are turned off to create a better quality projection. The image projected is adjusted and focussed on the screen. Once the image is focussed the fluid is introduced into the channel using a pipette. The flow of fluid through the channel is monitor, since the field of view on the projected image is very small only a part of the channel is viewed. The reservoir of the channel is focussed and viewwd for defects during the flow. The fluid used in the micro channel was whole milk as the milk is viscous in comparison to a water based dye, this helps in analyzing the defects. The experiment is repeated with all the sets, Ballistic press, Hydraulic press and Laser press. The projected images of the channels are as shown below.

Ballistic press

Figure-37

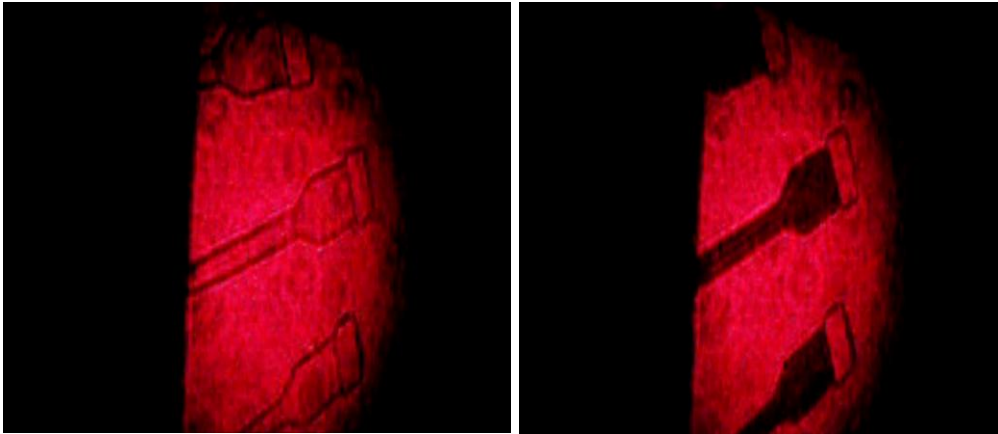


Fig: Image shows a channel of ballistic press before and after the flow.

Hydraulic press

Figure-38

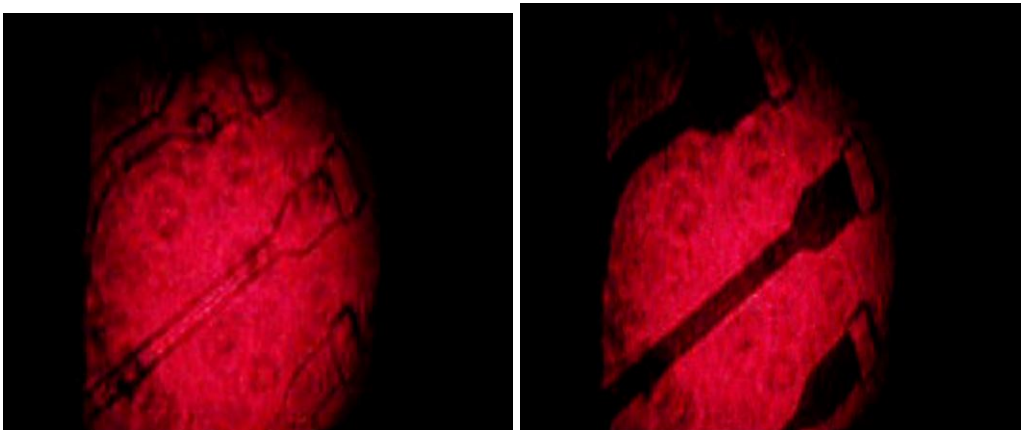


Fig: Image shows a channel of hydraulic press before and after the flow.

Laser press

Figure-39

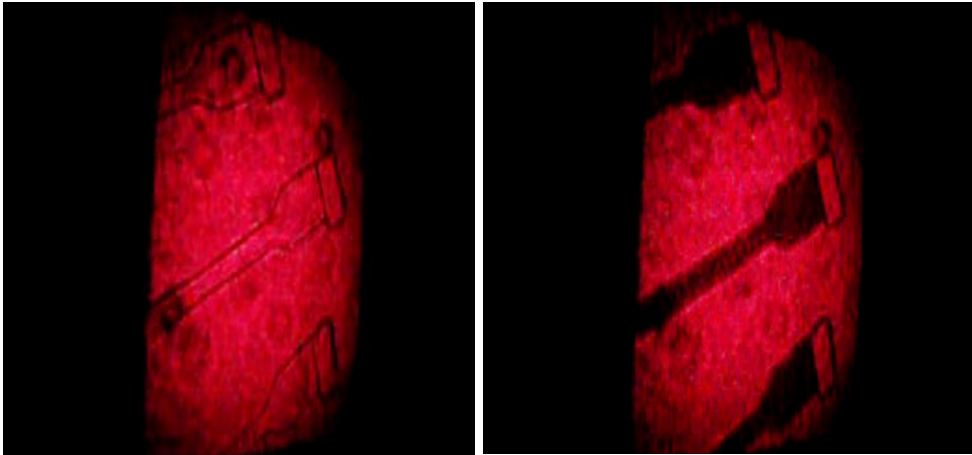


Fig: Image shows a channel of laser press before and after the flow.

The experiment is carried out on 30 samples each of Hydraulic press, Ballistic press and laser press. The images captured are edited and analyzed for the Average flow duration, Standard deviation and the variance the results and charts are discussed in the results and discussion section.

Chapter 4

RESULTS AND DISCUSSION.

4.1 Image processing and analysis of water flowing through the canal.

The images of water flowing through a canal is captured using a digital camera, these images are stored in a datalogger, the images are retrieved using a cellular modem which is connected to the datalogger. The images are retrieved using logger net software which establishes a connection between the datalogger and the workstation using an active internet connection to connect to the cellular modem.

The images retrieved are process in matlab using advanced image processing functions to determine the level of water. The images are converted to gray scale, cropped and the contrast of the images are adjusted to determine the level of water. The contrast is adjusted using curve fitting technique. The equations used for determining the low and high intensity values are given below.

$$\text{Low in} = 0.003589*B - 4.022e-6*V;$$

$$\text{High in} = 0.004327436*B + 7.04752e-9*V$$

Where B and V are the mean and the variance of the grayscale image determined from the histogram data.

The equations for low and high intensity values are determined using curve fitting technique is described below. The equations can be represented in the form of

$$Ax=b$$

Where A is a matrix of the mean and variance of the intensity values. The matrix is of a 2xn Dimension.

The matrix b is the intensity low and high input intensity values determined from trial and error. Let b-low and b-high be the low and high intensity input values in the matlab function imadjust.

We have x is the low in and high in intensity input values to be used in matlab using the curve fitting technique.

The matrices used are shown below.

Table-5

Matrix A	
Mean	Variance
190.1634	3085.756
106.4162	1777.98
172.9345	4415.085
126.0862	2421.341
132.5402	2845.483
137.2556	2871.097
134.1966	3616.998
149.9577	4556.185
185.2259	3516.141
207.9857	3006.383
129.7425	2352.962
108.9915	1875.477
176.7056	4226.065
127.0046	2265.784
135.5462	3082.734
136.822	2930.628
134.9555	3287.82
146.7874	4709.853
184.0917	3730.044
205.948	3232.667
134.5122	2777.735
102.6394	1763.076

Matrix b-low and b-high	
b-low	b-high
0.65	0.8
0.4	0.5
0.65	0.75
0.45	0.6
0.45	0.6
0.45	0.6
0.45	0.6
0.5	0.6
0.65	0.8
0.75	0.85
0.45	0.6
0.4	0.5
0.65	0.75
0.45	0.6
0.45	0.6
0.45	0.6
0.5	0.6
0.65	0.8
0.75	0.85
0.45	0.6
0.35	0.45

173.5063	4340.756
125.7195	2351.17
132.3237	3164.259
130.6944	3186.248
147.6466	4781.136
184.8094	3730.544
209.9589	3231.378
135.0568	2709.347
103.0763	1698.714
173.806	4339.71
153.1523	4775.175
126.4598	2388.548
136.6129	3590.803
134.5188	3112.905
133.2045	3907.06
147.0159	4767.832
186.0779	3633.794
211.8446	3057.731
132.3902	2446.776
102.3533	1657.754
175.6141	4452.666
155.3056	4963.455
124.6545	2242.399
134.5669	3129.659
134.1671	2834.56
132.2553	3223.271
142.6401	4961.506
187.8755	3912.483
210.1801	3207.766
135.653	2450.164
103.9297	1716.682
174.4258	4375.456
147.2913	5346.913
130.3749	2544.019
134.4665	3281.114
135.6263	2964.766
132.4623	3408.196

0.65	0.75
0.45	0.6
0.45	0.6
0.45	0.6
0.5	0.6
0.65	0.8
0.75	0.85
0.45	0.6
0.35	0.45
0.65	0.75
0.55	0.65
0.45	0.6
0.45	0.6
0.45	0.6
0.45	0.6
0.5	0.6
0.65	0.8
0.75	0.85
0.45	0.6
0.35	0.45
0.65	0.75
0.6	0.7
0.45	0.55
0.45	0.6
0.45	0.6
0.45	0.6
0.45	0.6
0.65	0.8
0.75	0.85
0.45	0.6
0.35	0.45
0.65	0.75
0.5	0.6
0.45	0.6
0.45	0.6
0.45	0.6
0.45	0.6

$$x = \begin{pmatrix} \text{Low in} \end{pmatrix} = (A^T A)^{-1} (A^T b\text{-low})$$

$$x = \begin{pmatrix} \text{HIGH in} \end{pmatrix} = (A^T A)^{-1} (A^T b\text{-high})$$

x is obtained by solving the above set of matrices with b-low and b-high

$$(A^T A)^{-1} = \begin{bmatrix} 1.24675760433768 E - 05 & 5.33157625068708 E - 07 \\ -5.33157625068707 E - 07 & 2.42460826042633 E - 08 \end{bmatrix}$$

$$(A^T b\text{-low}) = \begin{pmatrix} 4702.59962916404 \\ 103241.617352586 \end{pmatrix}$$

$$(A^T b\text{-high}) = \begin{pmatrix} 5818.72708988058 \\ 127950.804025315 \end{pmatrix}$$

$$x = (\text{low in}) = \begin{pmatrix} 0.003585963 \\ -4.02207 E - 06 \end{pmatrix}$$

$$x = (\text{high in}) = \begin{pmatrix} 0.00432747566897425 \\ 7.04751601694753 E - 09 \end{pmatrix}$$

the equations used in matlab function imadjust is as written below.

$$\text{Low in} = 0.003589 * B - 4.022e-6 * V;$$

$$\text{High in} = 0.004327436 * B + 7.04752e-9 * V$$

Where B and V are as mentioned earlier the mean and the variance.

The results of the level of water shown in the table below. These results are obtained using the above expressions to adjust the contrast of the image which in turn is used to determine the level of water.

The matlab program to obtain the water level.

```
close all;
clear all;
```

```
% reading an image
```

```

I=imread('test15660.jpg');

%converting an image to gray scale
Im=rgb2gray(I);
figure, imshow(Im);

% crop the region of Interest.
I1 = imcrop(Im,[370 333 110 214]);

% MEAN AND STANDARD DEVIATION
B=mean2(I1);
b=std2(I1);
V=b^2;

%Adjusting the Contrast of the image.
C1=0.003589*B-4.022e-6*V;
C2=0.004327436*B+7.04752e-9*V;
P=imadjust(I1,[C1 C2],[,]);

%Defining the Co-ordinates for Pixel to Feet Conversion.
A=[1:213'];
for i=1:213;
    n(i)=(214-A(i))*0.00939;
end

% Intensity profile-1
x1=[33 80];
y1=[1 213];
c=improfile(P,x1,y1);
figure()
plot(n,c);
axis([0 1.0 0 300]);
set(gca,'XTick',0:0.05:1.0)
xlabel('Water level in Feet')
ylabel('Intensity')
title('Intensity profile of processed image-1')

% Intensity profile-2
x2=[53 65];
y2=[1 213];
c2=improfile(P,x2,y2);
figure()
plot(n,c2);
axis([0 1.0 0 300]);
set(gca,'XTick',0:0.05:1.0)
xlabel('Water level in Feet')
ylabel('Intensity')
title('Intensity profile of processed image-2')

% Intensity profile-3
x3=[83 70];
y3=[1 213];

```

```

c3=improfile(P,x3,y3);
figure()
plot(n,c3);
axis([0 1.0 0 300]);
set(gca,'XTick',0:0.05:1.0);
xlabel('Water level in Feet')
ylabel('Intensity')
title('Intensity profile of processed image-3')

figure, imshow(P)

% Calculating the Level of water from the intensity plot-1
check=0;
for N=1:203
    if (c2(N)==0 && c2(N+1)==0 && c2(N+2)==0 && c2(N+3)==0 && c2(N+4)==0 &&
c2(N+5)==0 && c2(N+6)==0 && c2(N+7)==0 && c2(N+8)==0 && c2(N+9)==0 &&
c2(N+10)==0 && check==0)
        level1=N;
        check=1;
    end
end
% Calculating the Level of water from the intensity plot-2
check=0;
for N=1:203
    if (c(N)==0 && c(N+1)==0 && c(N+2)==0 && c(N+3)==0 && c(N+4)==0 && c(N+5)==0
&& c(N+6)==0 && c(N+7)==0 && c(N+8)==0 && c(N+9)==0 && c(N+10)==0 && check==0)
        level2=N;
        check=1;
    end
end
% Calculating the Level of water from the intensity plot-3
check=0;
for N=1:203
    if (c3(N)==0 && c3(N+1)==0 && c3(N+2)==0 && c3(N+3)==0 && c3(N+4)==0 &&
c3(N+5)==0 && c3(N+6)==0 && c3(N+7)==0 && c3(N+8)==0 && c3(N+9)==0 &&
c3(N+10)==0 && check==0)
        level3=N;
        check=1;
    end
end
% Actual height of water from processed Image
Height1=(213-level1)*0.00939;
Height2=(213-level2)*0.00939;
Height3=(213-level3)*0.00939;

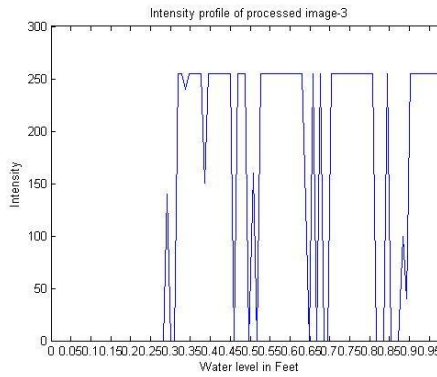
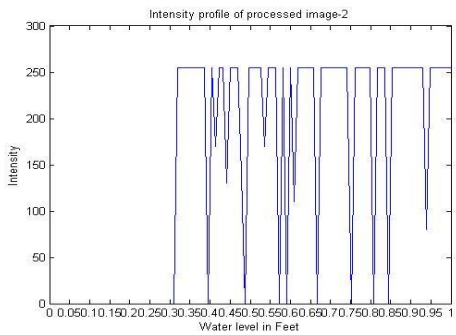
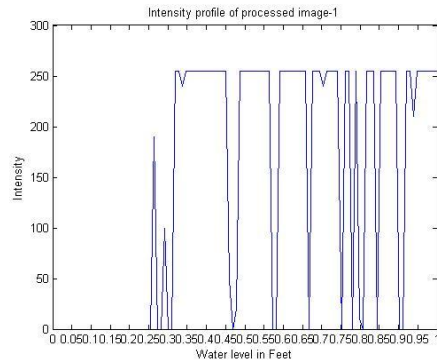
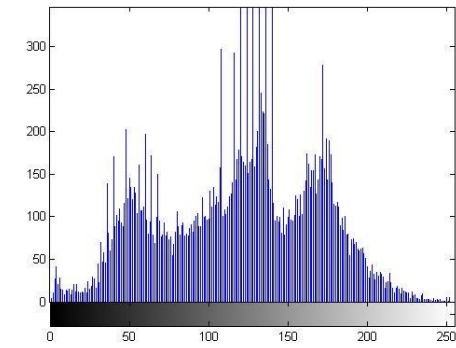
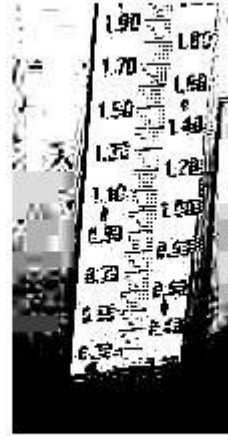
% Average taken to determine the level of water.
waterlevel=(Height1+Height2+Height3)/3;

```

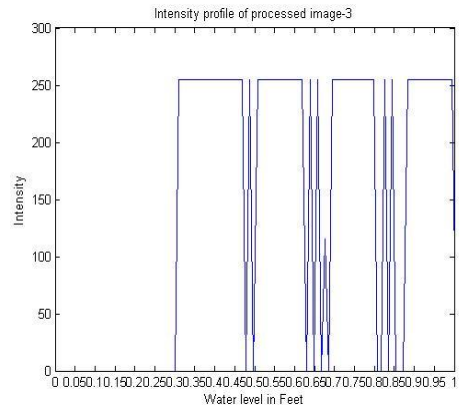
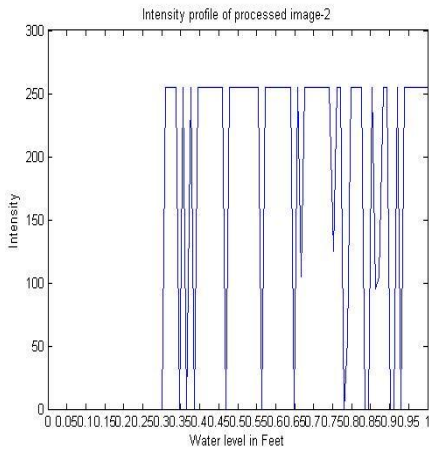
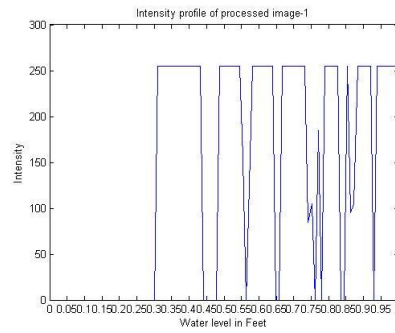
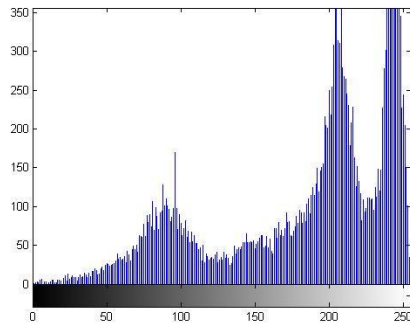
Data shows the images retrieved and processed for October 9th obtained using the Matlab code.

Figure-40.

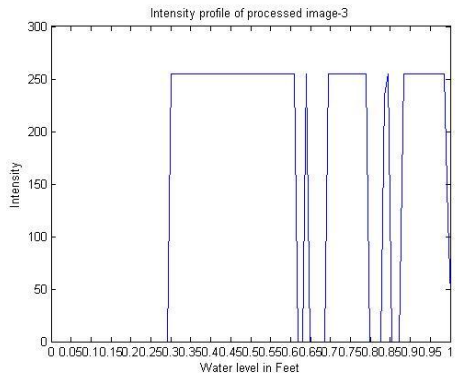
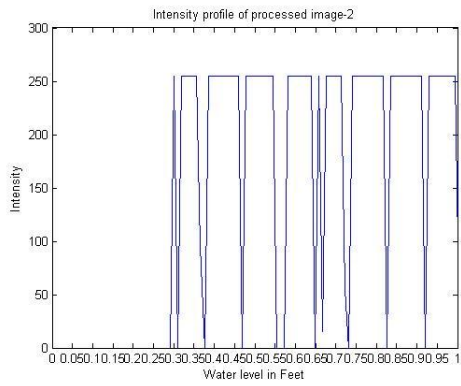
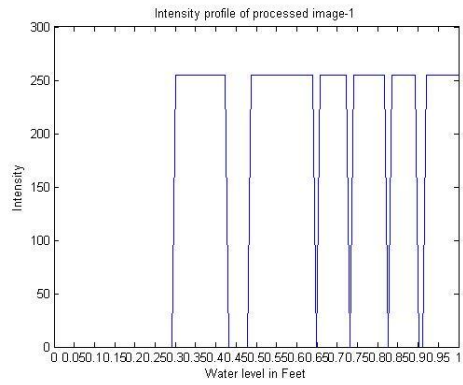
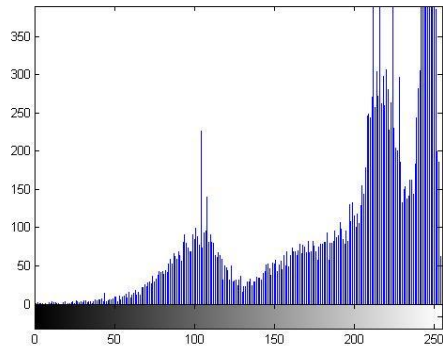
7:00 AM



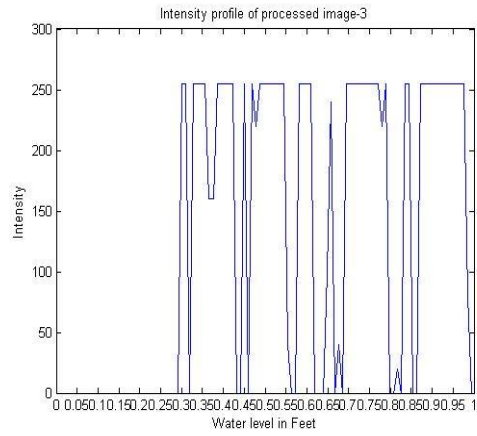
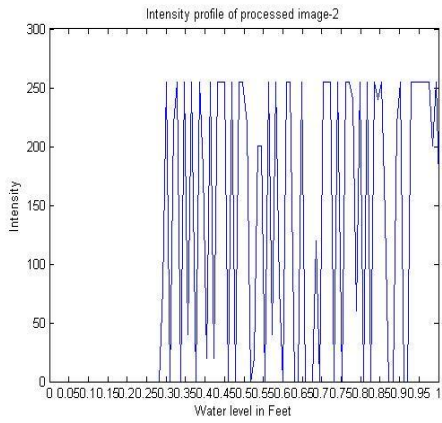
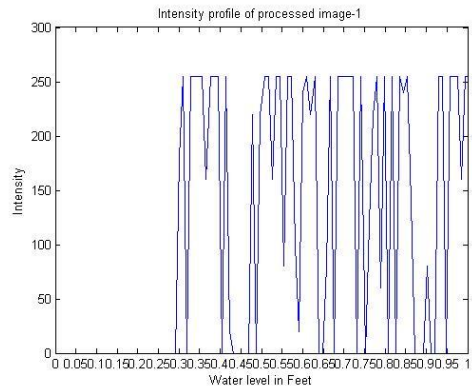
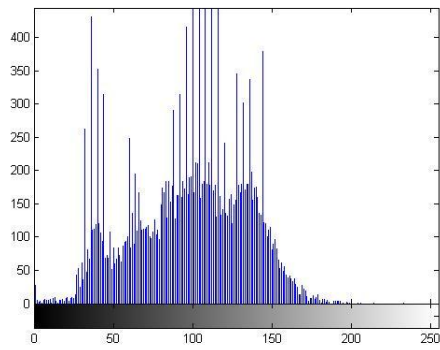
8:00 AM



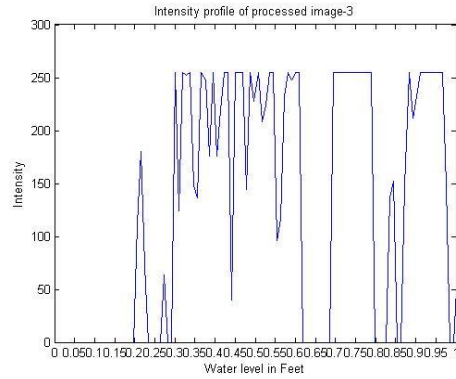
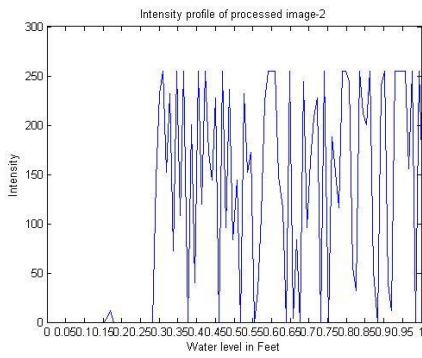
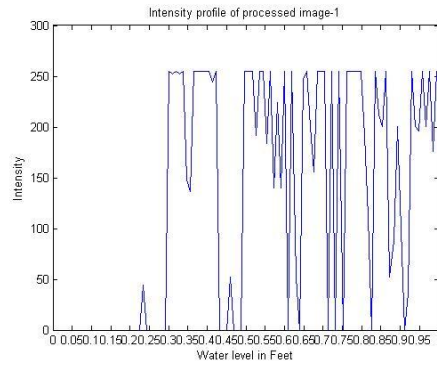
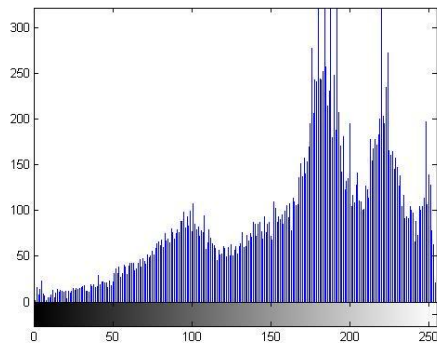
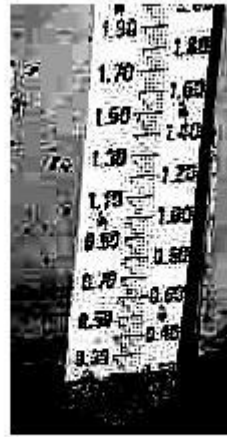
9:00 AM



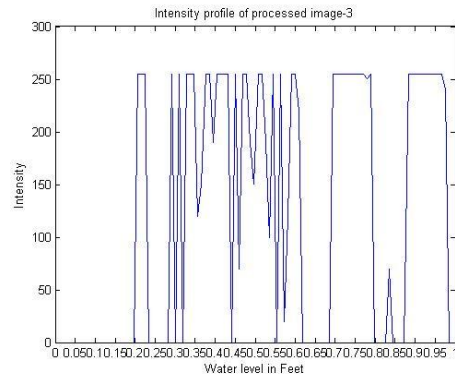
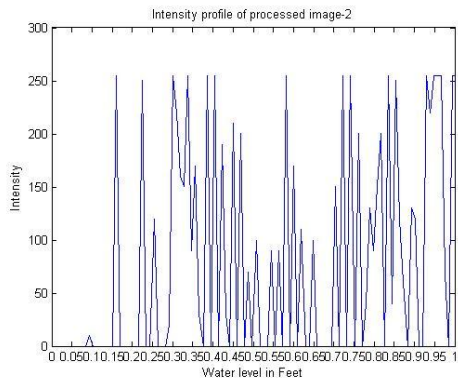
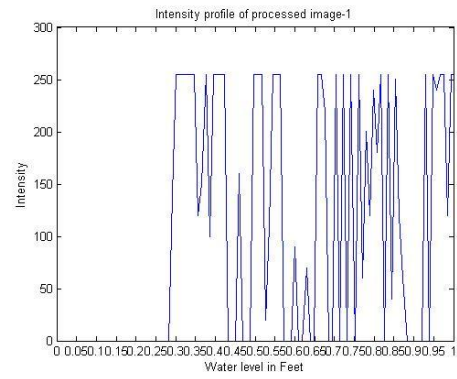
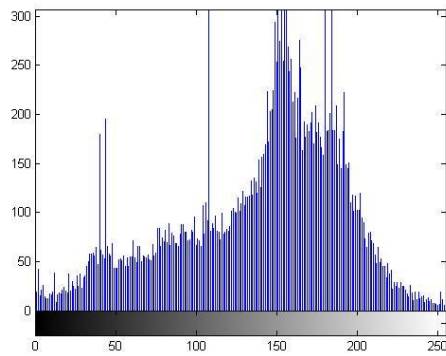
11:00 AM



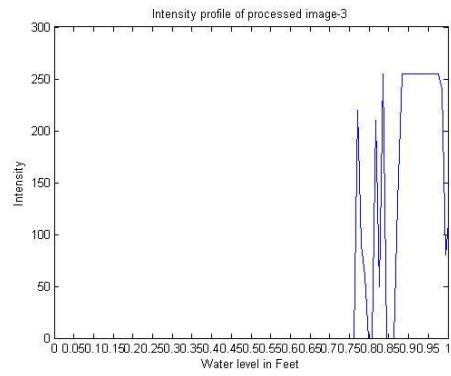
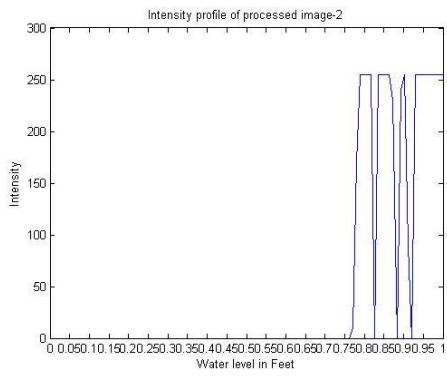
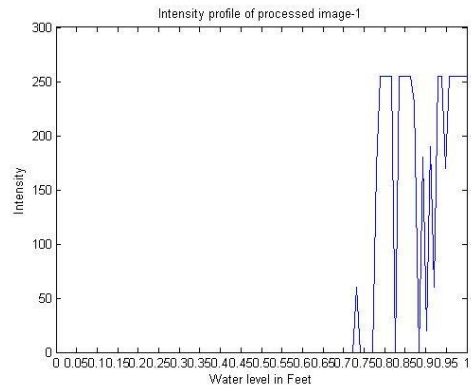
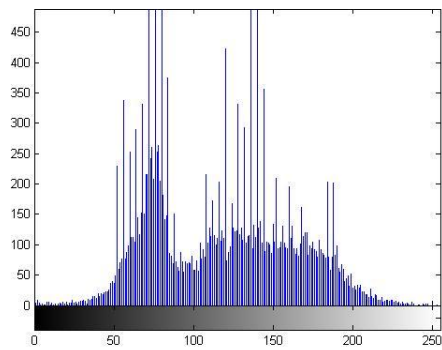
12:00 PM



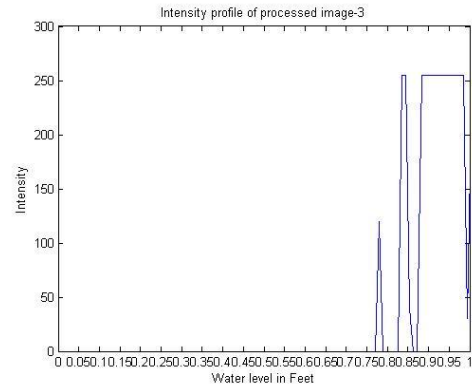
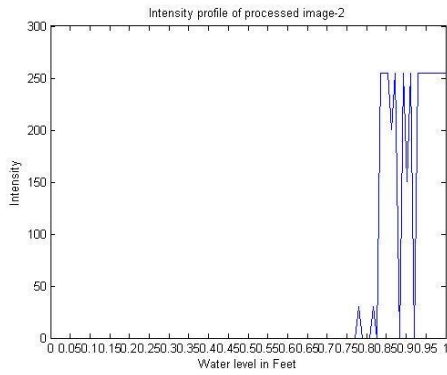
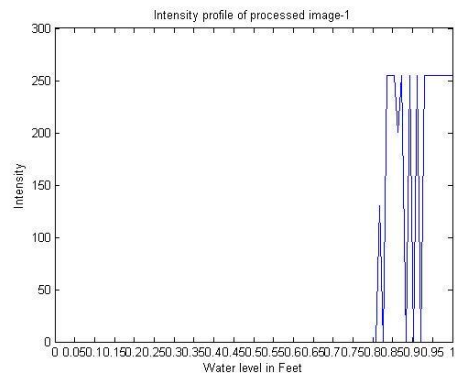
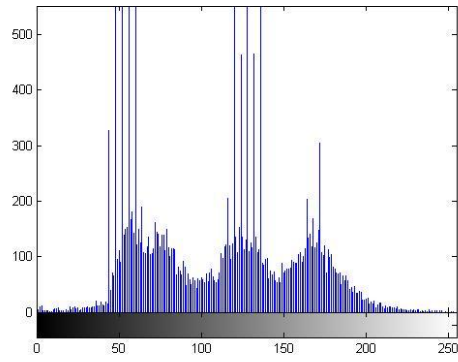
1:00 PM



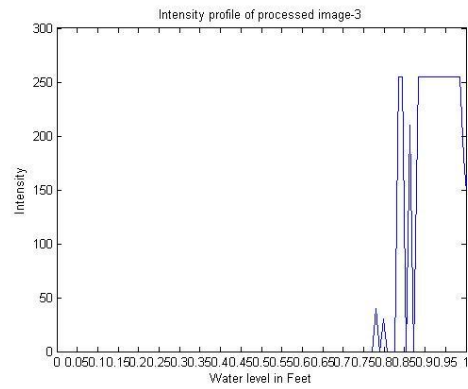
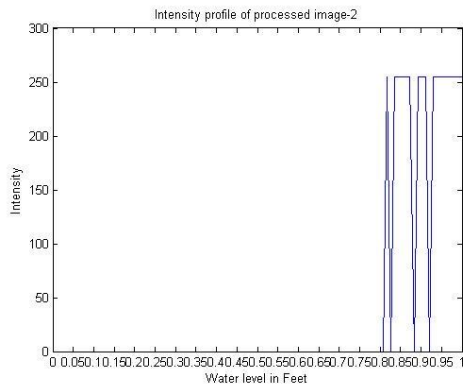
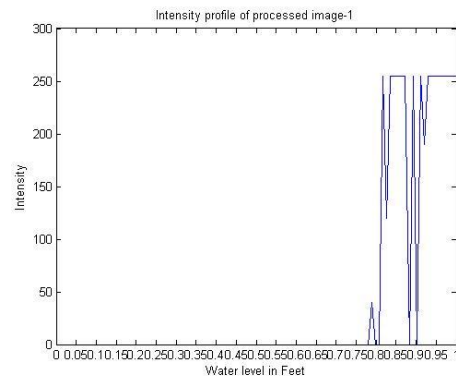
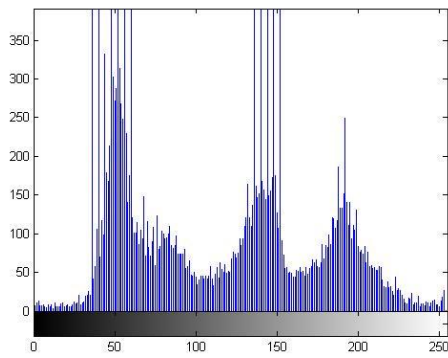
2:00 PM



3:00 PM



4:00 PM



5:00 PM

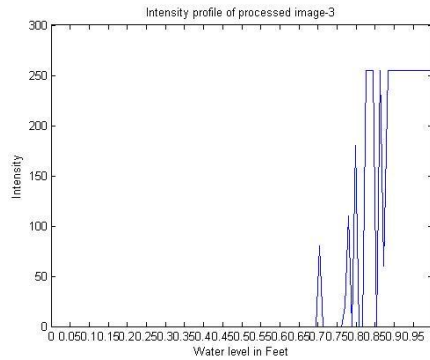
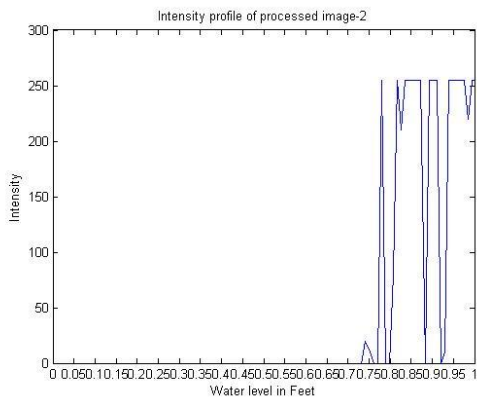
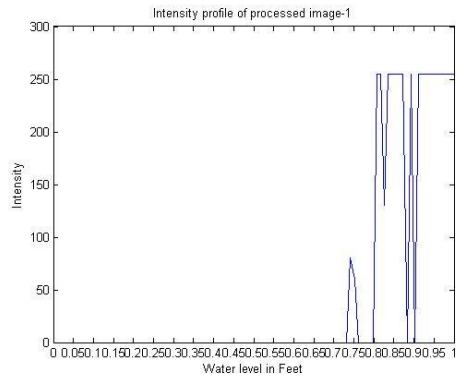
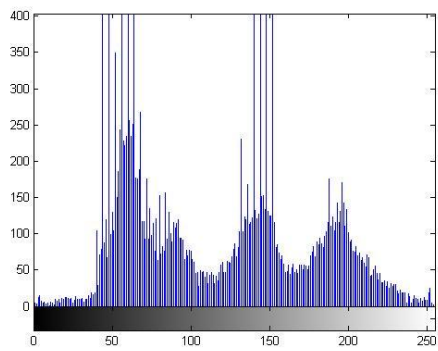


Table-6

Date	Time	Pixel Value	Water Level (ft.)
October 9th	7:00 AM	181	0.303485
	8:00 AM	182	0.294095
	9:00 AM	182	0.294095
	10:00 AM	182	0.294095
	11:00 AM	182	0.294095
	12:00 PM	183	0.284705
	1:00 PM	183	0.284705
	2:00 PM	130	0.782375
	3:00 PM	128	0.801155
	4:00 PM	128	0.801155
	5:00 PM	129	0.791765

Table shows the data of water level for an entire day.

Figure- 41

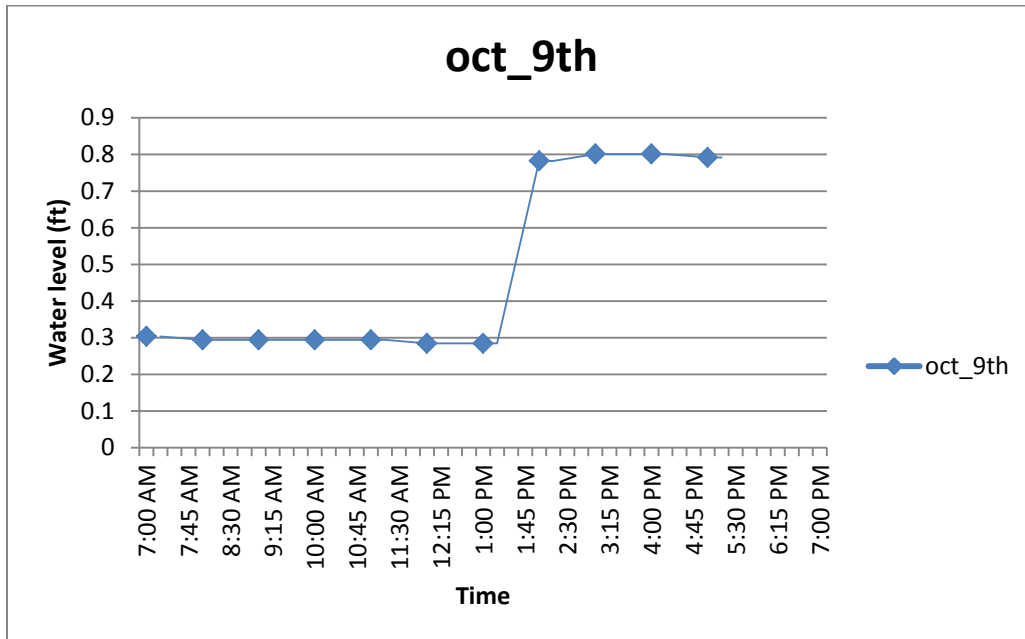


Chart shows the level of water as monitored during the entire day.

Data has been archived for many months which shows the raw image and contrast adjusted image and the pixel intensity plots showing the level of water.

4.2 High speed imaging analysis of a fluid flowing through a micro channel.

High speed imaging is carried out to be able to analyze the flow of fluid in a micro channel. The fluid travels across a micro channel very quickly this makes analyzing the fluid a challenge, to simplify this experiment the video is captured at 420fps. The duration of flow for all the channels are observed and tabulated. The videos while analyzed are played back at 29fps this is considerably slower than actual time taken for the fluid to traverse the channel. The real time needed for the fluid to flow in the micro channel is given by the expression.

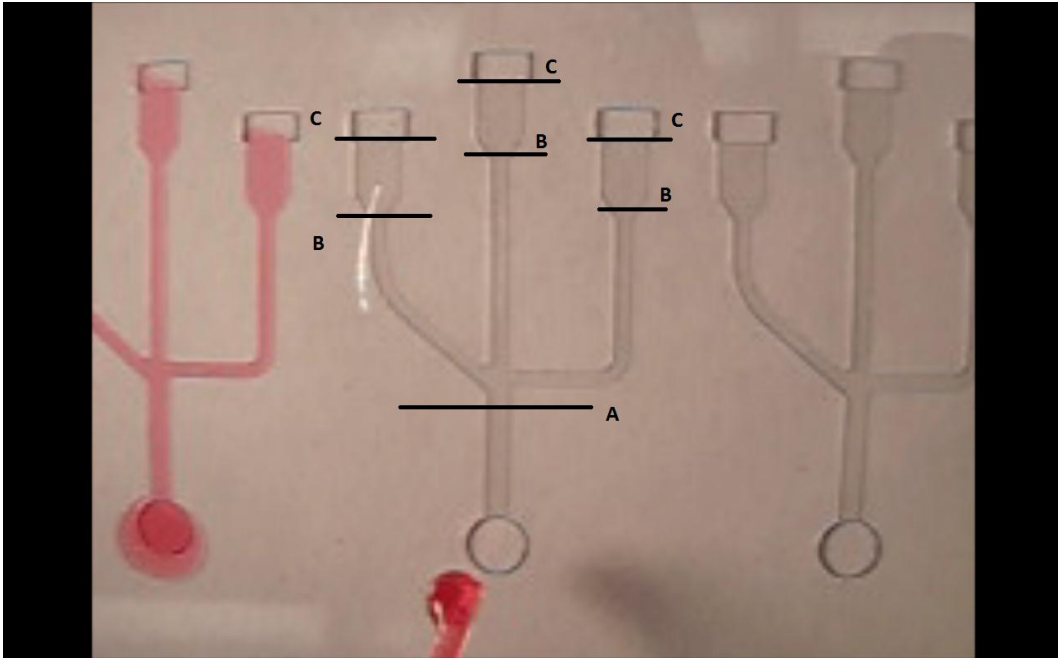
Duration of flow in real time in seconds

$$= \text{Time observed during playback} * \frac{29\text{fps}}{420\text{fps}}$$

The results are tabulated using the above expression the average, standard deviation and variance is calculated and plotted for the entire channel and reservoir for all the three press i.e. Ballistic press, Hydraulic Press, Laser press.

The results tabulated and charts for water based dye as fluid are shown below for Ballistic press, Hydraulic Press, Laser press.

Figure-42



The flow duration is calculated for the entire channel point A to C, and for the reservoir point B to C. The flow times for all the 3 channels in a sample are tabulated as below.

Table-7

Ballistic Press.

Flow time for Ballistic Press						
	Left channel (Inclined)		Center Channel		Right Channel (Perpendicular)	
	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)
Mean	1.262	2.357	1.275	2.461	1.320	2.805
Standard deviation	0.029	0.036	0.027	0.040	0.040	0.039
Variance	0.001	0.001	0.001	0.002	0.002	0.002

Table-8.

Hydraulic Press

Flow time for Hydraulic Press						
	Left channel (Inclined)		Center Channel		Right Channel (Perpendicular)	
	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)
Mean	1.247	2.361	1.247	2.455	1.298	2.825
Standard deviation	0.076	0.068	0.051	0.061	0.041	0.063
Variance	0.006	0.005	0.003	0.004	0.002	0.004

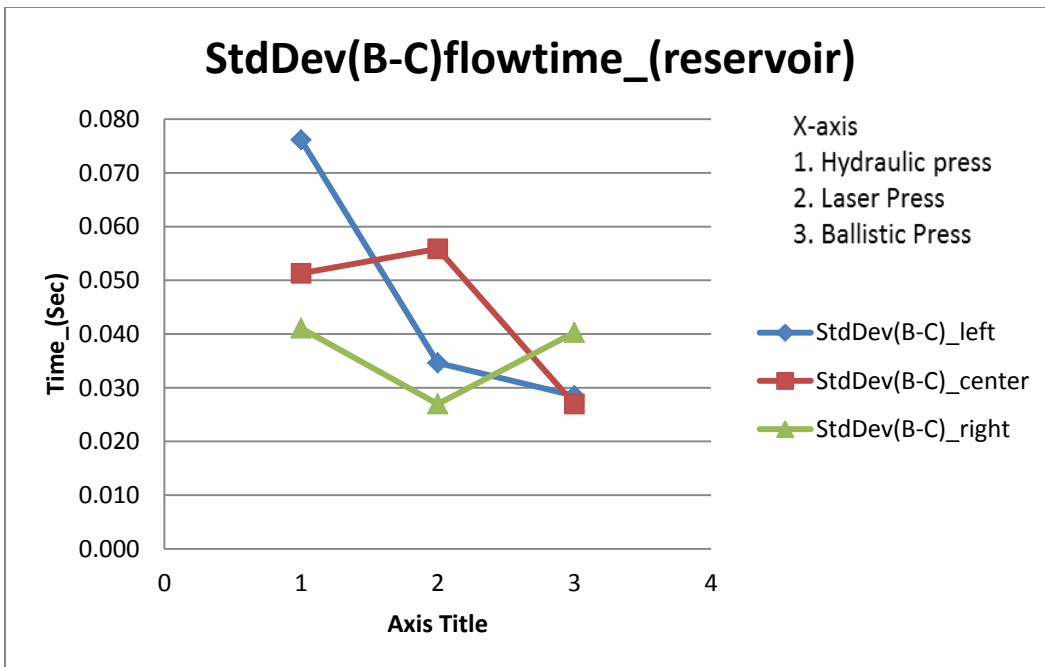
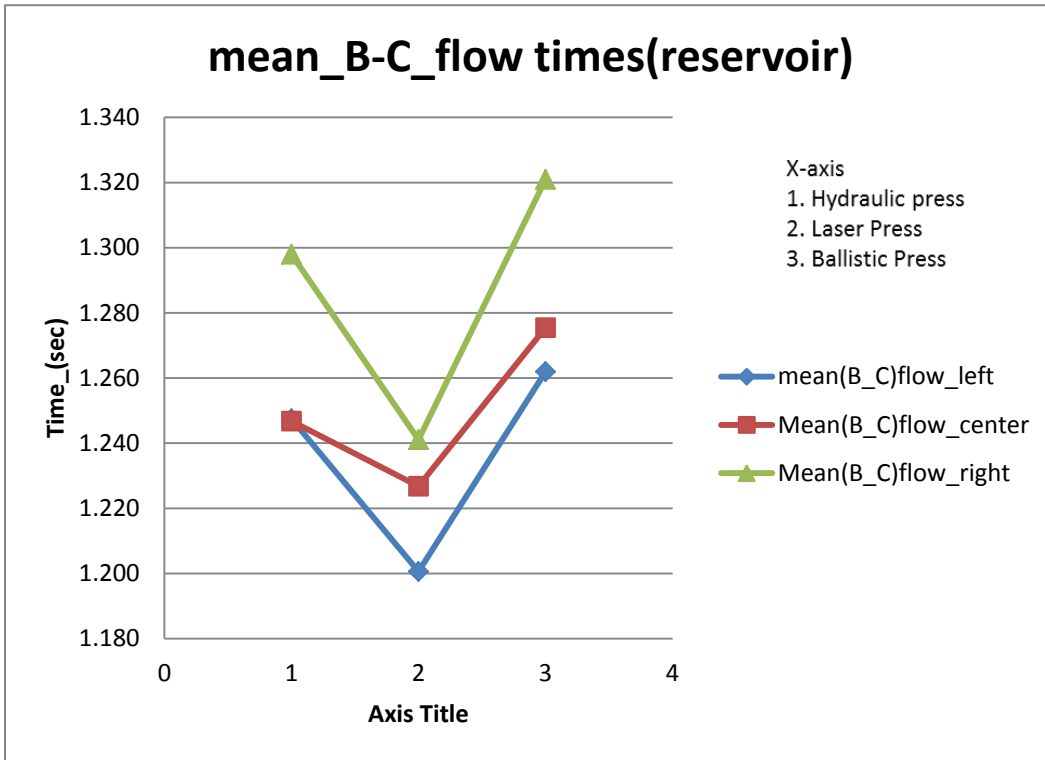
Table-9

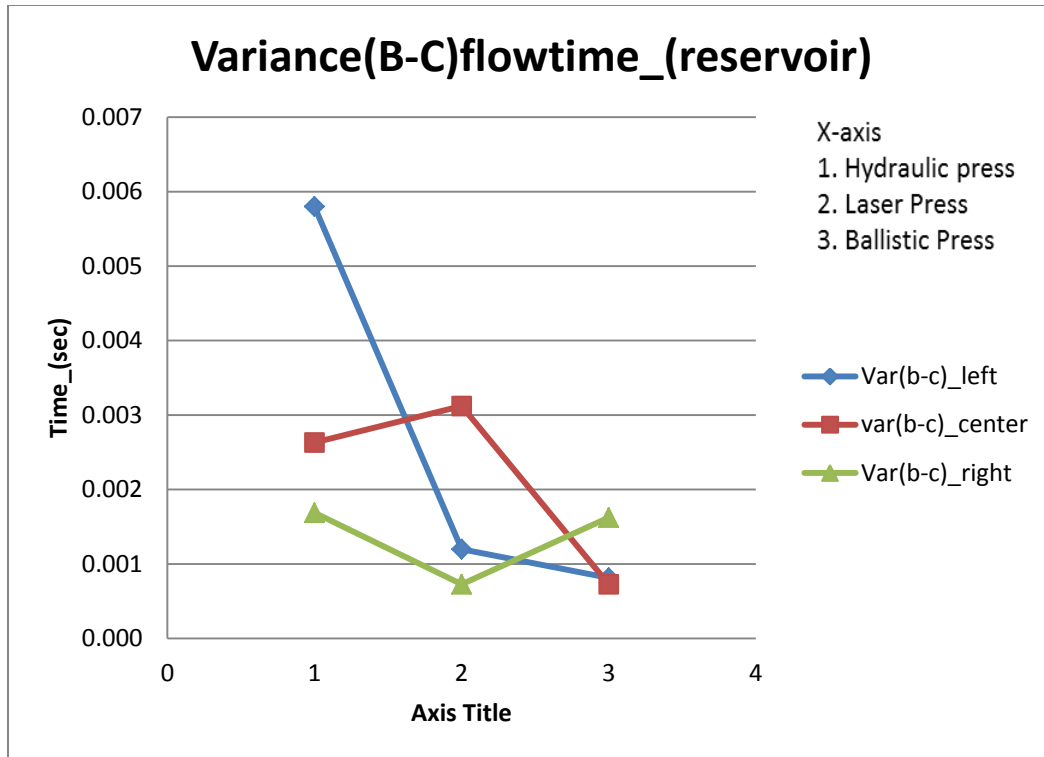
Laser Press

Flow time for Laser Press						
	Left channel (Inclined)		Center Channel		Right Channel (Perpendicular)	
	Reservoir B-C (sec)	Channel A-C (sec)	Reservoir B-C (sec)	Channel A-C (sec)	Reservoir B-C (sec)	Channel A-C (sec)
Mean	1.201	2.337	1.227	2.442	1.241	2.772
Standard deviation	0.035	0.041	0.056	0.098	0.027	0.025
Variance	0.001	0.002	0.003	0.010	0.001	0.001

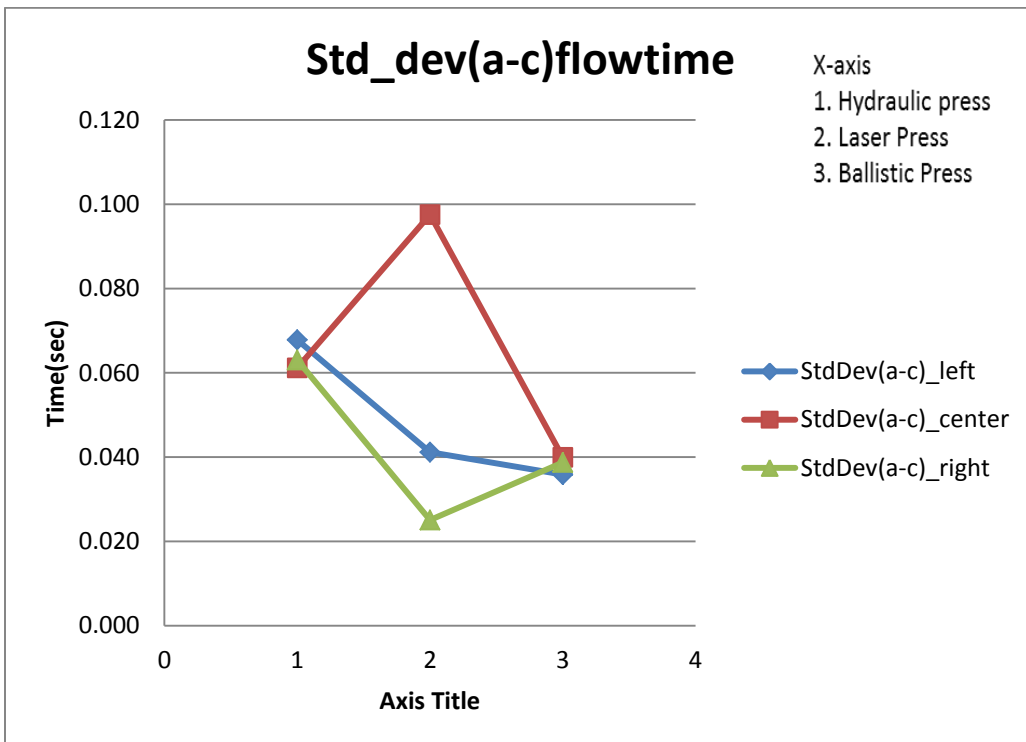
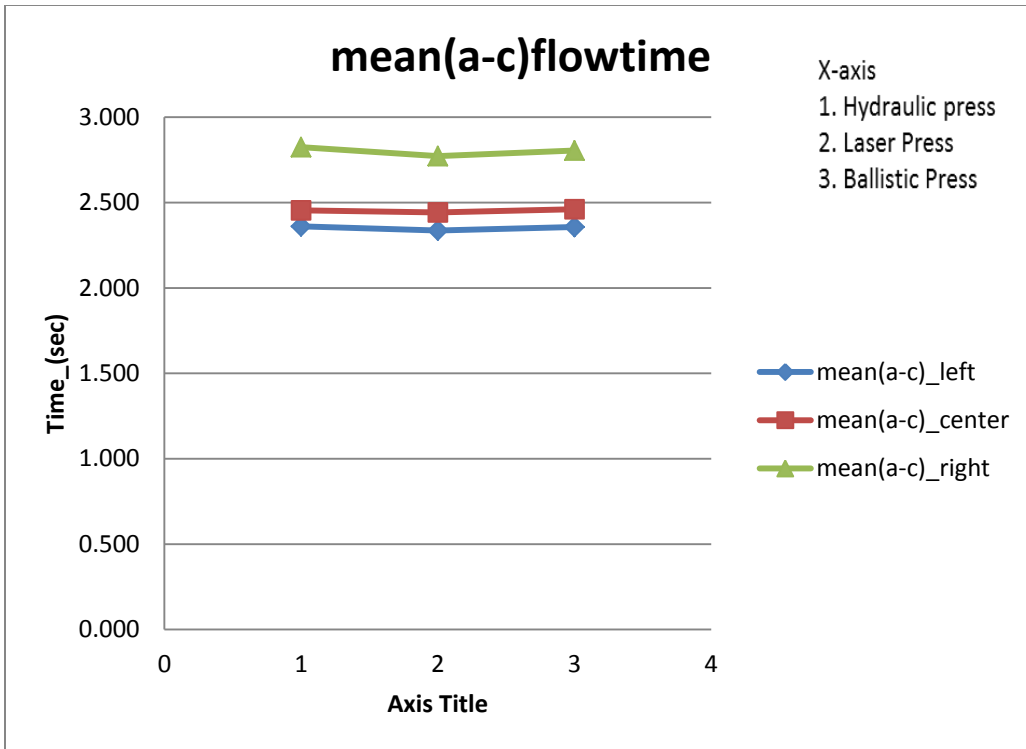
The charts for the above data are shown below.

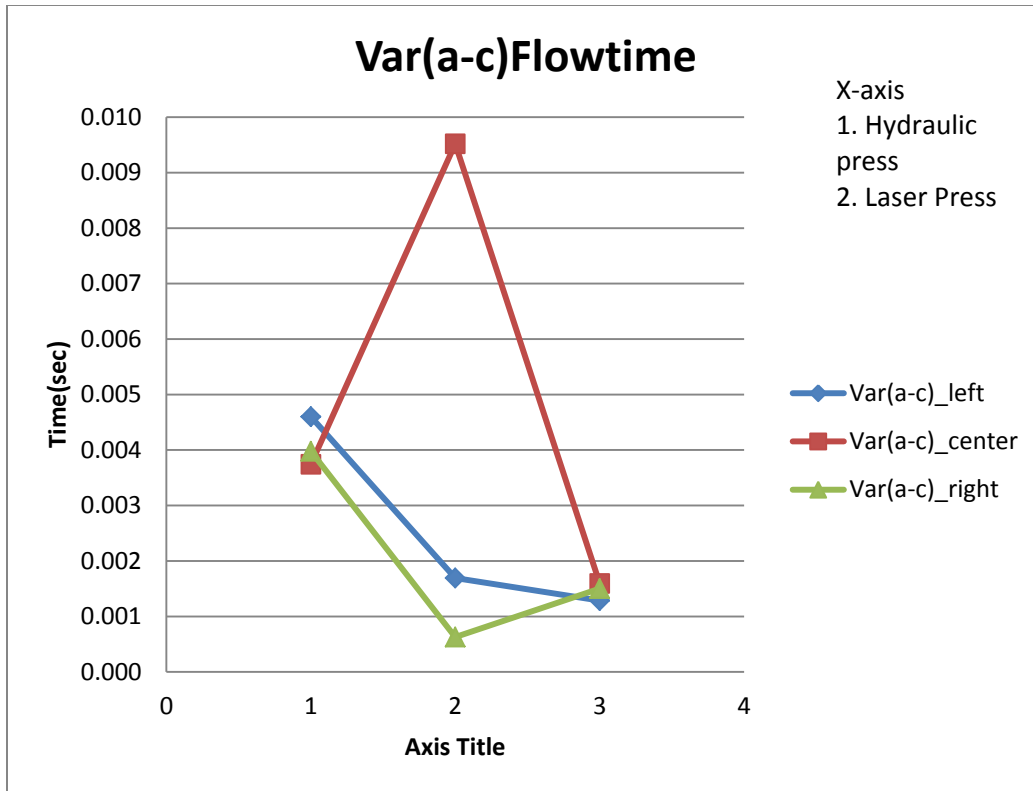
Figure-43





The Charts above show the mean, standard deviation and variance of flow duration of the reservoir for water based dye as fluid.

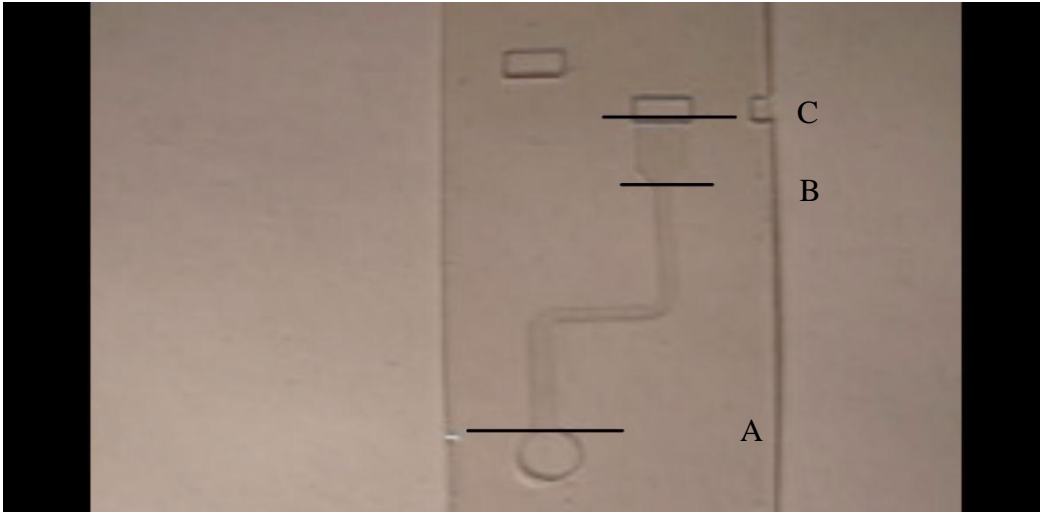




The charts above show the Mean, standard deviation and variance of flow durations for the entire channel for water based dye as the fluid. The data points 1,2,3 on the x-axis represents the

For the single channel rotary press using water based dye as the fluid the data is collected in the similar manner as the 3 channel sample. The mean, standard deviation and variance of flow duration is calculated in real time. The duration of flow is calculated for the entire channel(A-C) and for the reservoir(B-C).

Figure-44



Single channel data points for a dye

The results for the rotary press using water based dye as a fluid is tabulated below.

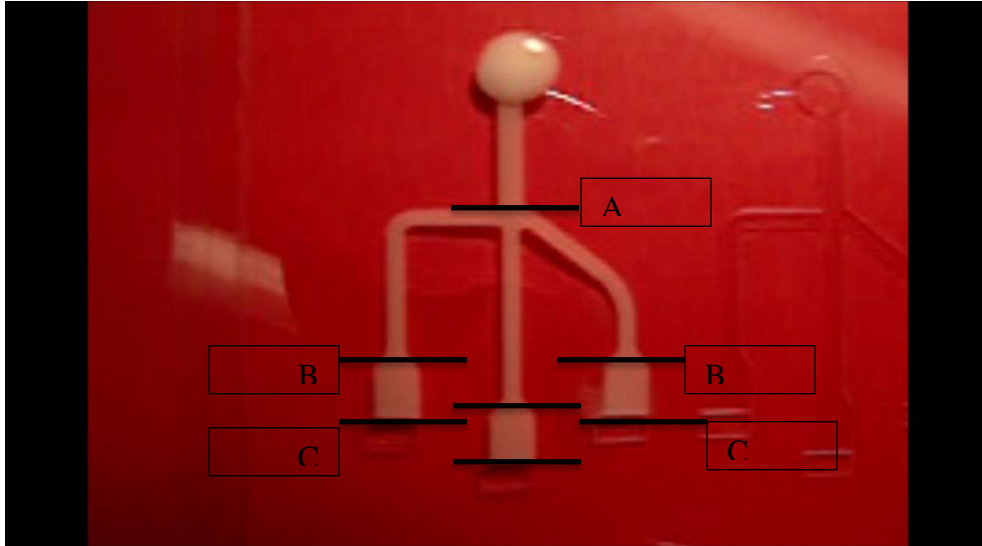
Table-10

	Reservoir (B-C) sec	Entire channel (A-C) Sec
Mean	0.931069	2.108331
Standard Deviation	0.026617	0.057937
Variance	0.000708	0.003357

The experiment was initially conducted using water based dye, the viscosity of water being very less the fluid would travel through the channel very quickly, using a much more viscous fluid such as whole milk would slow the fluid flowing through the channel and helps in analyzing the flow pattern or observe any defects in the press. The experiment was conducted in similar manner as the 3 channel press and the single channel rotary and stamped press. Fluid was

introduced into the channel and the flow duration was observed and tabulated for the entire channel (A-C) and for the reservoir (B-C)

Figure-45



All the data including the defects are tabulated and shown below.

Table-11

Laser Press

Flow time for Laser Press						
	Right channel (Inclined)		Center Channel		Left Channel (Perpendicular)	
	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)
Mean	2.9766	5.8037	2.8606	5.8759	2.8474	6.7780
Standard deviation	0.2518	0.2519	0.0764	0.1241	0.0892	0.1183
Variance	0.9181	0.9192	0.0912	0.2229	0.1152	0.2026

Table-12.

Hydraulic Press

Flow time for Hydraulic Press						
	Right channel (Inclined)		Center Channel		Left Channel (Perpendicular)	
	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)
Mean	2.9425	5.5884	2.9610	5.8085	2.9809	6.6430
Standard deviation	0.1301	0.1833	0.1189	0.1982	0.1222	0.2225
Variance	0.2451	0.4868	0.2047	0.5691	0.2162	0.7169

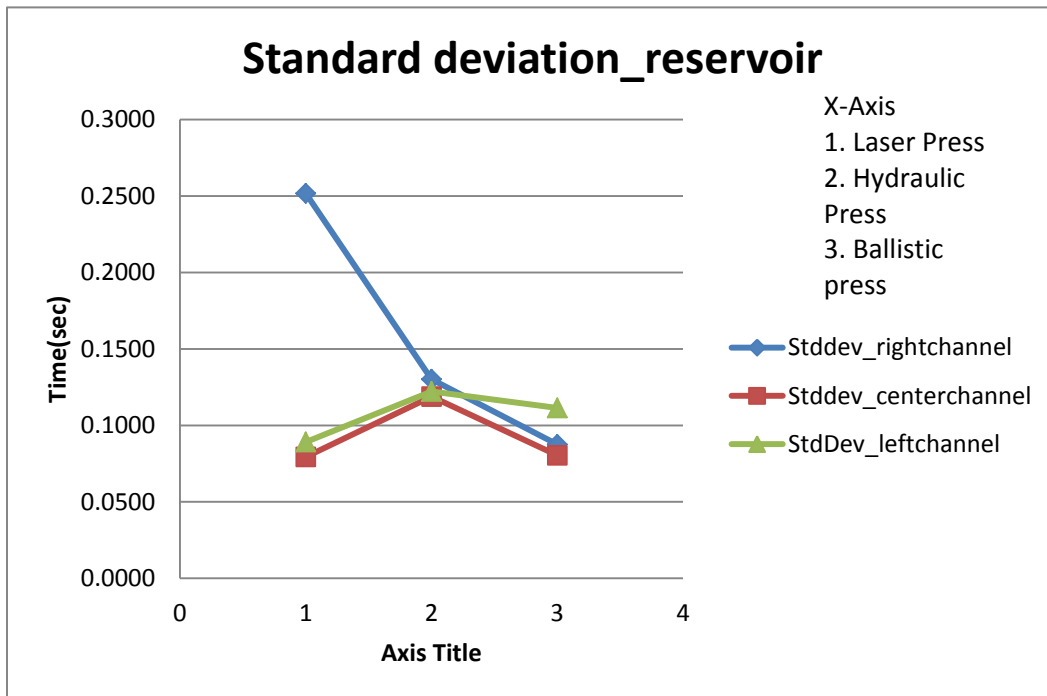
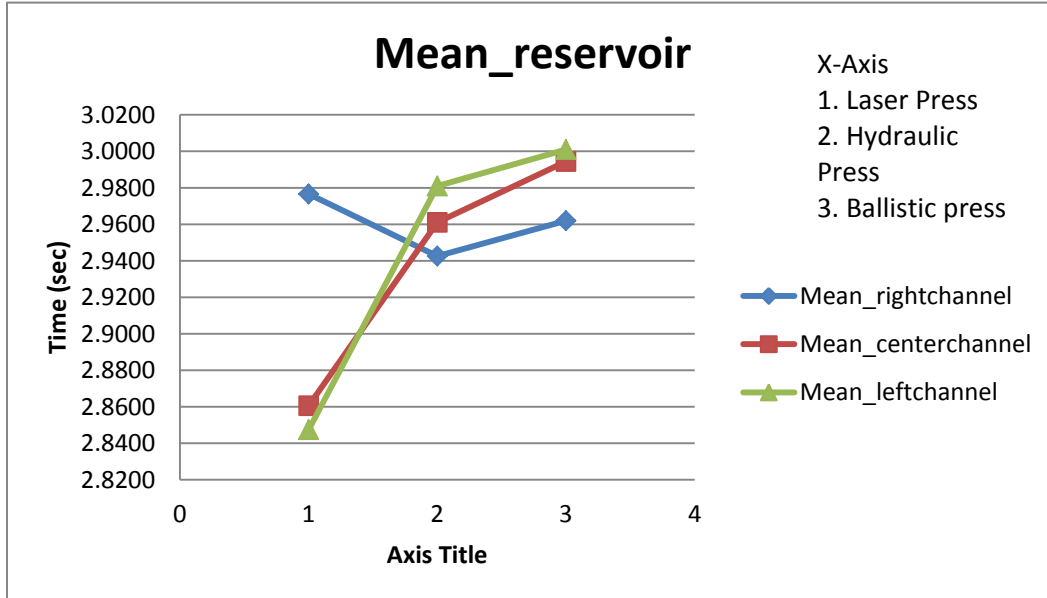
Table-13.

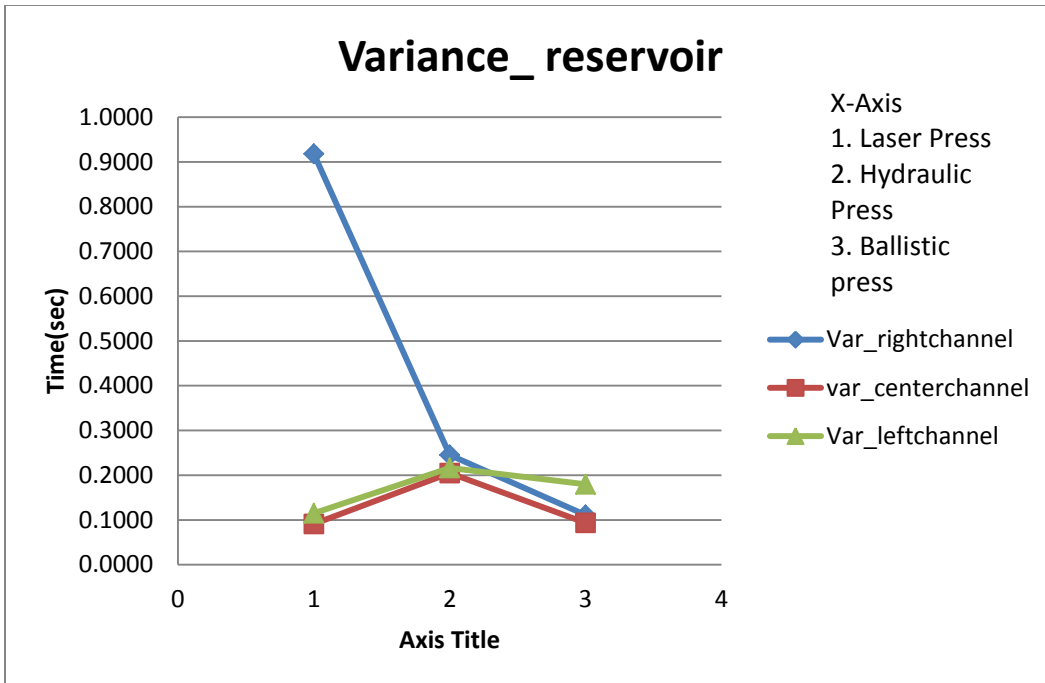
Ballistic Press

Flow time for Ballistic Press						
	Right channel (Inclined)		Center Channel		Left Channel (Perpendicular)	
	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)
Mean	2.9620	5.8133	2.9944	6.0900	3.0010	6.9216
Standard deviation	0.0875	0.6373	0.0804	0.6212	0.1114	0.6275
Variance	0.1110	5.8817	0.0936	5.5894	0.1797	5.7023

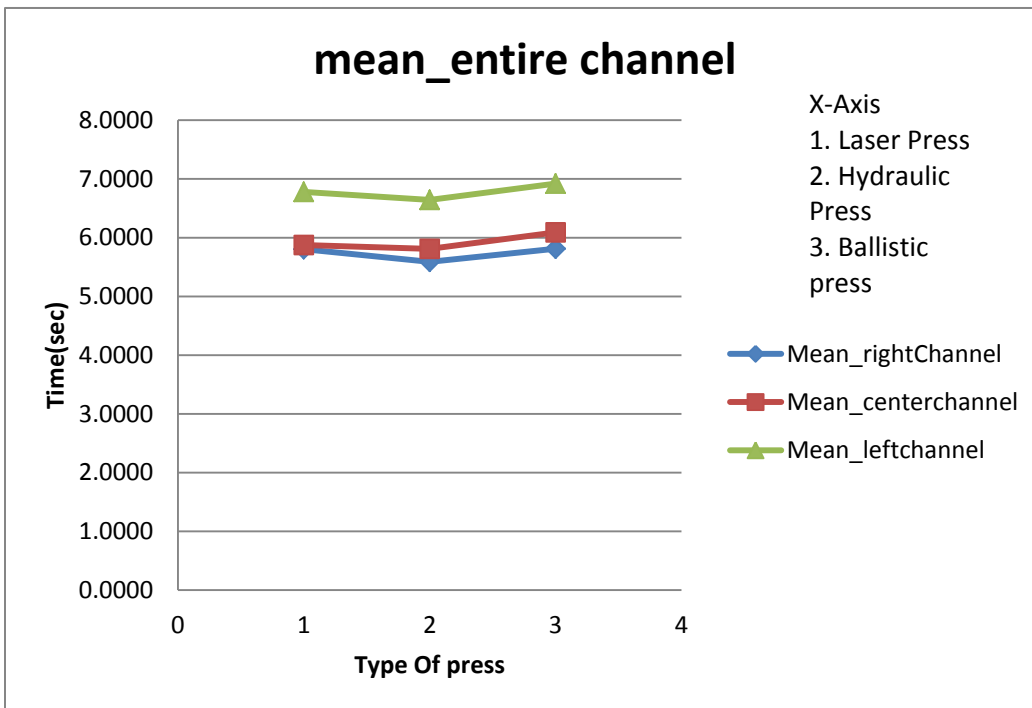
The charts for the above data using whole milk as a fluid is plotted below. The plots show the flow durations for reservoir and the entire 3 channel sample.

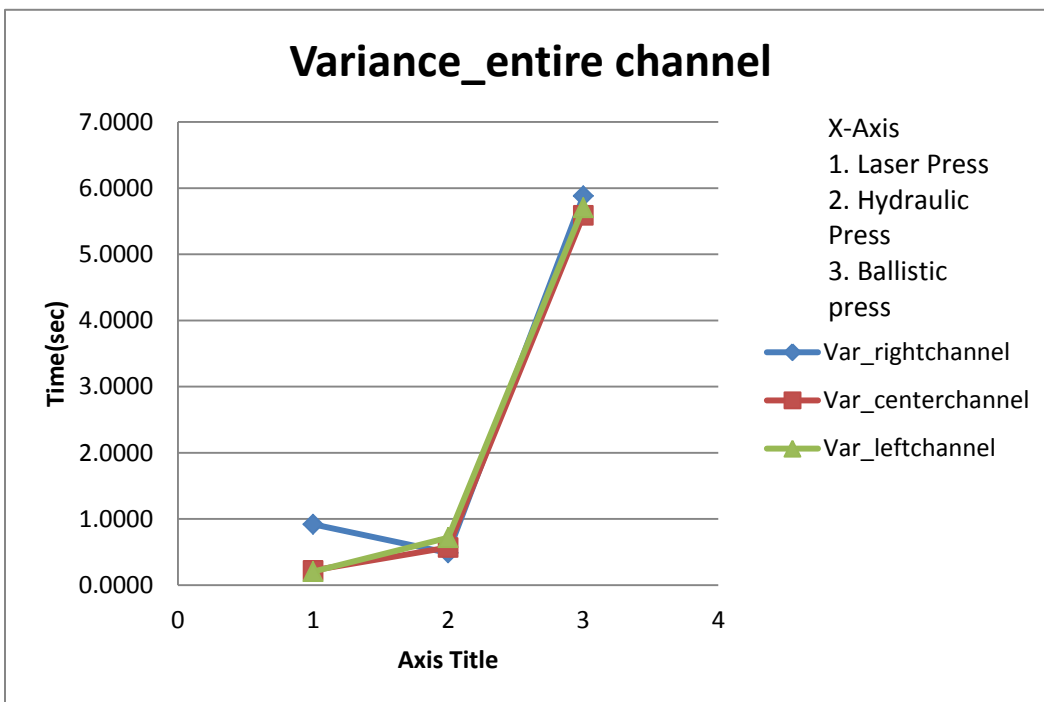
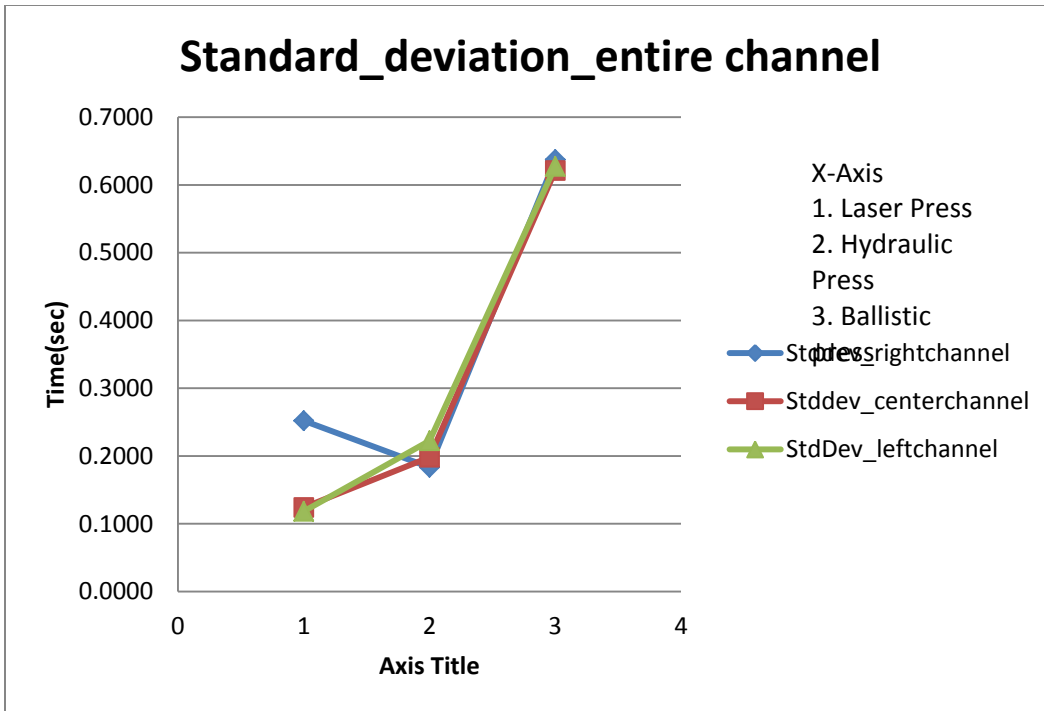
Figure-46





The Plots above show the mean, standard deviation and variance of flow duration for the reservoir for which the fluid used is whole milk.





The Plots above show the mean, standard deviation and variance of flow duration for the entire channel for which the fluid used is whole milk.

It is observed that the data collected with milk had defects which effected the over all flow duration of the fluid. These defects are observed vary from a minimal flow deformation to a more prominent damage in the press. The data collected with milk was observed to have many number of these defects the data was revised by removing the defective samples from the initial data set. The revised data set is as tabulated below.

Table-14

Ballistic Press

Flow time for Ballistic Press						
	Right channel (Inclined)		Center Channel		Left Channel (Perpendicular)	
	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)
Mean	2.960934	5.695125	2.993574	5.938512	2.999941	6.720324
Standard deviation	0.084538	0.145672	0.081769	0.151461	0.10522	0.150361
Variance	0.103516	0.307364	0.096845	0.332279	0.16036	0.327468

Table-15.

Hydraulic Press

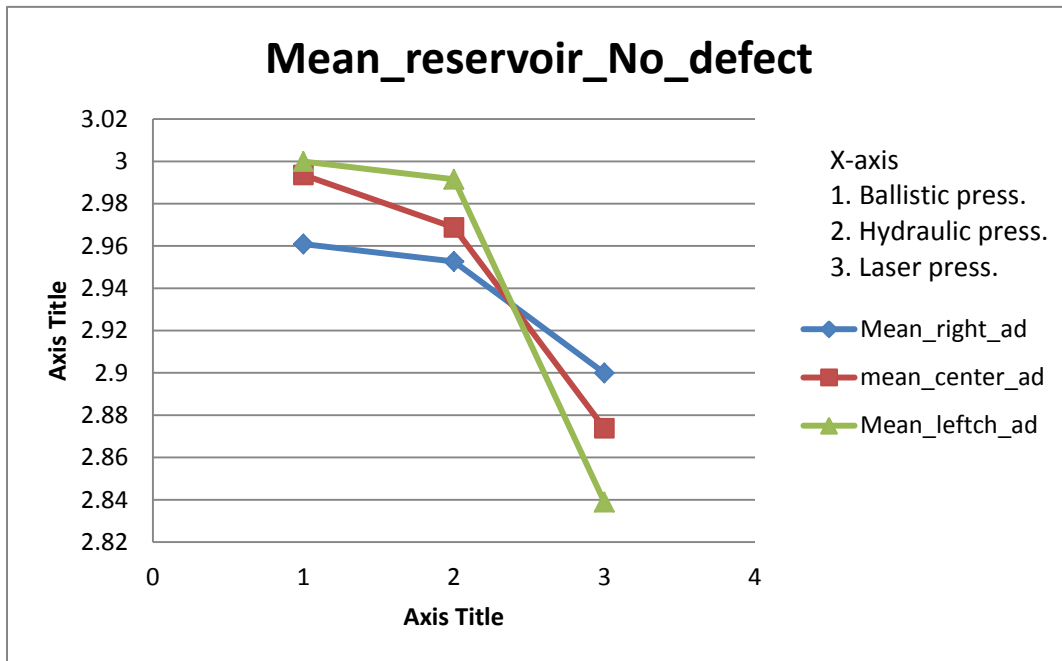
Flow time for Hydraulic Press						
	Right channel (Inclined)		Center Channel		Left Channel (Perpendicular)	
	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)
Mean	2.952687	5.611725	2.968797	5.797126	2.991542	6.620936
Standard deviation	0.125311	0.154939	0.116794	0.140495	0.115744	0.149206
Variance	0.227445	0.347711	0.19758	0.285903	0.194042	0.322458

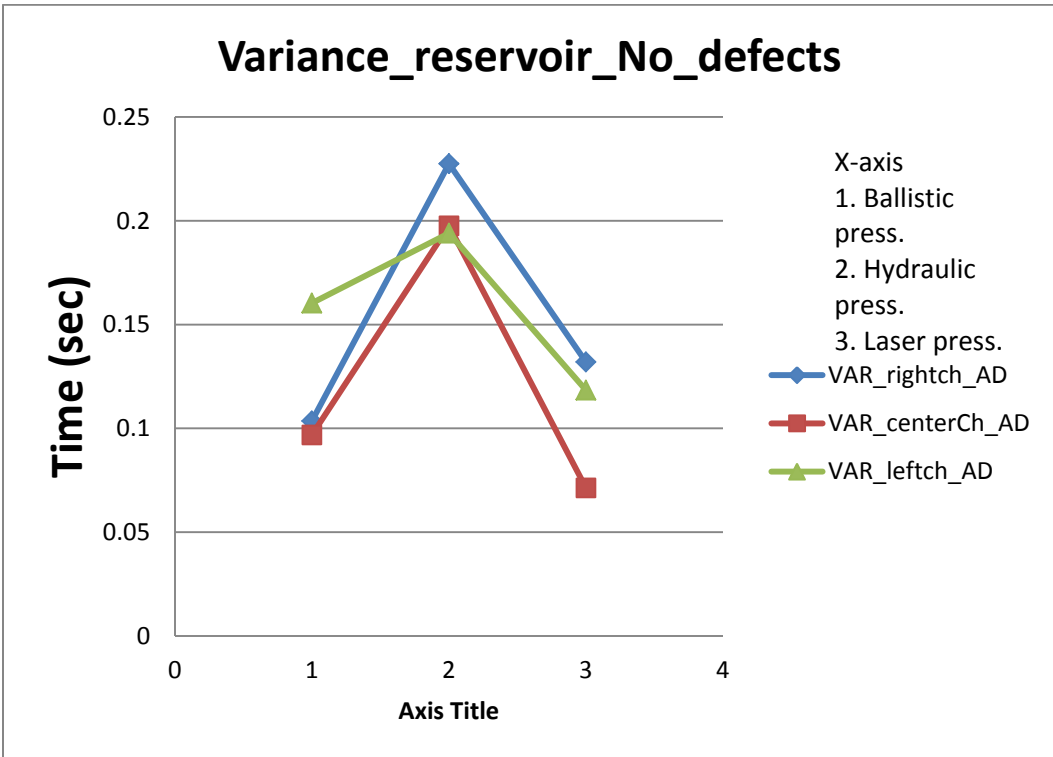
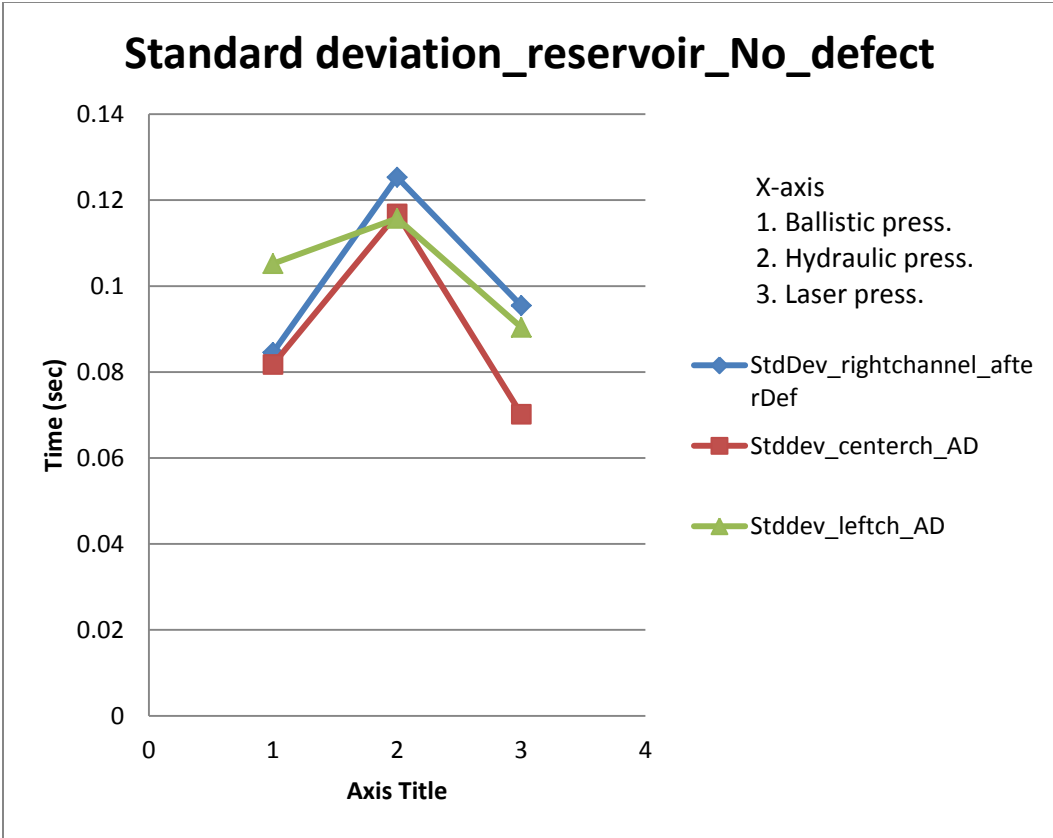
Table-16

Laser Press

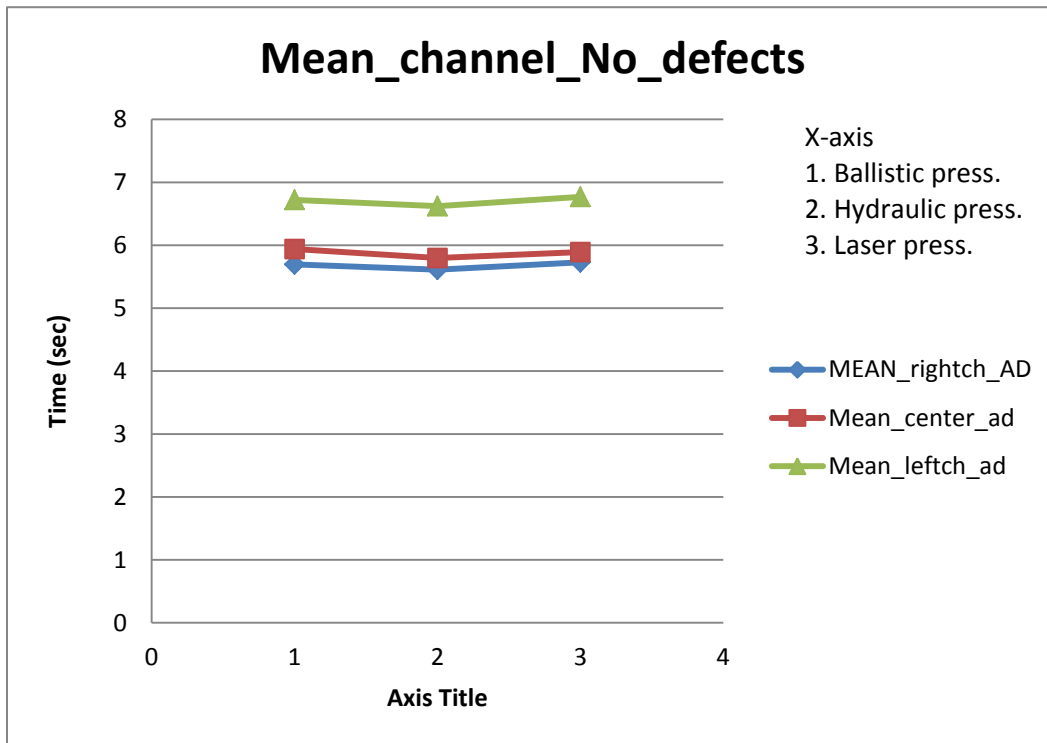
Flow time for Laser Press						
	Right channel (Inclined)		Center Channel		Left Channel (Perpendicular)	
	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)	Reservoir B-C (s)	Channel A-C (s)
Mean	2.899948	5.729054	2.873828	5.892449	2.838886	6.769372
Standard deviation	0.09545	0.105144	0.070181	0.110652	0.090409	0.103712
Variance	0.131963	0.160128	0.07134	0.177346	0.118393	0.155797

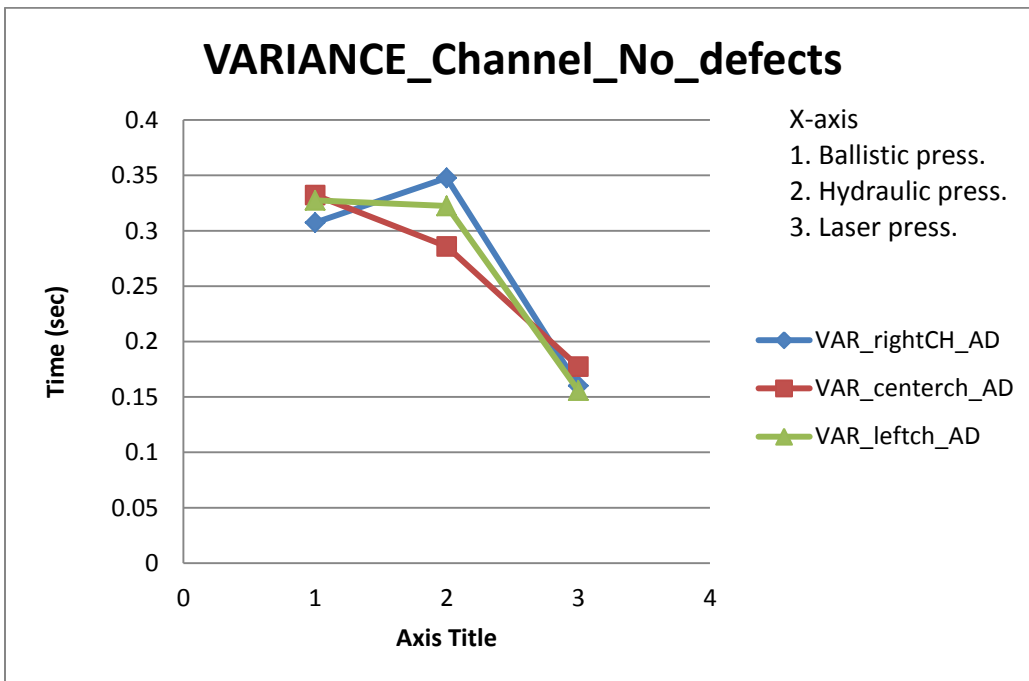
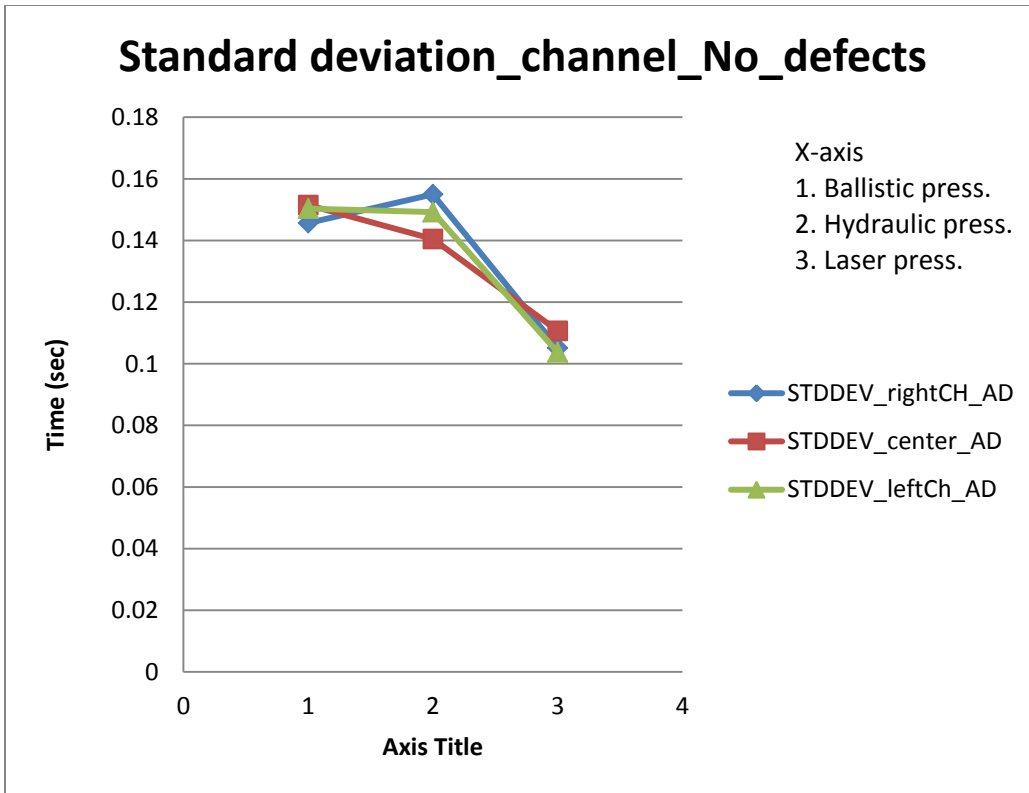
Figure-47





The Plots above show the mean, standard deviation and variance of flow duration for the reservoir without any defects, the fluid used is whole milk.

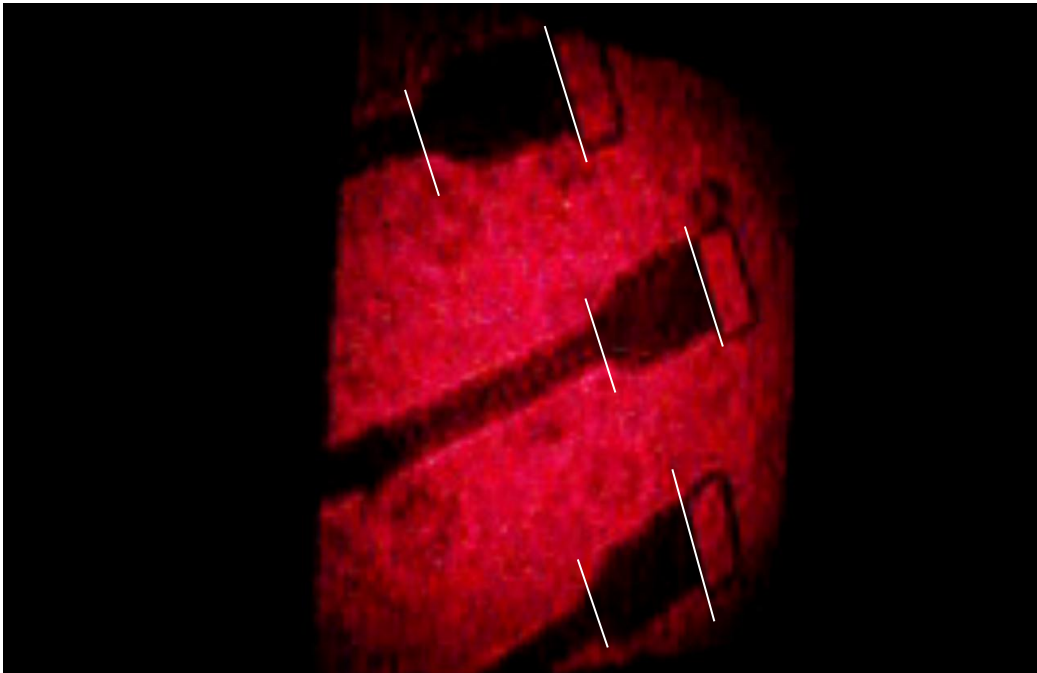




The Plots above show the mean, standard deviation and variance of flow duration for the entire channel without any defects, the fluid used is whole milk.

The defects observed in the samples are significant and had a large impact on the flow duration and flow pattern, to get a closer observation on the flow pattern and defects the samples were projected on to a screen using a laser, this enlarges the field of view giving a better insight on the defects. The sample was tested using whole milk as fluid.

Figure-48



The duration of flow is measured for the reservoir as marked on the image for all the three channels, the results are tabulated as below.

Table-17.

Laser Press

Flow time for Laser Press			
	Right channel (Inclined)	Center Channel	Left Channel (Perpendicular)
	Reservoir B-C (s)	Reservoir B-C (s)	Reservoir B-C (s)
Mean	2.897	3.018	3.065
Standard deviation	0.173	0.126	0.455
Variance	0.108	0.057	0.750

Table-18

Hydraulic Press

Flow time for Hydraulic Press			
	Right channel (Inclined)	Center Channel	Left Channel (Perpendicular)
	Reservoir B-C (s)	Reservoir B-C (s)	Reservoir B-C (s)
Mean	3.452	3.510	3.638
Standard deviation	0.129	0.123	0.121
Variance	0.017	0.015	0.015

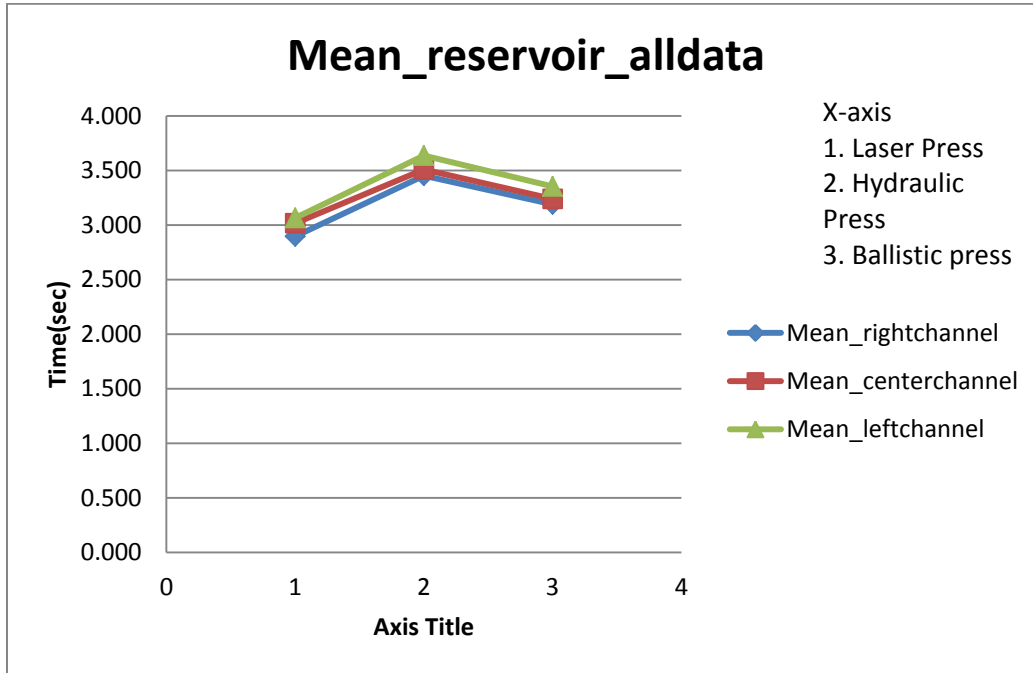
Table-19.

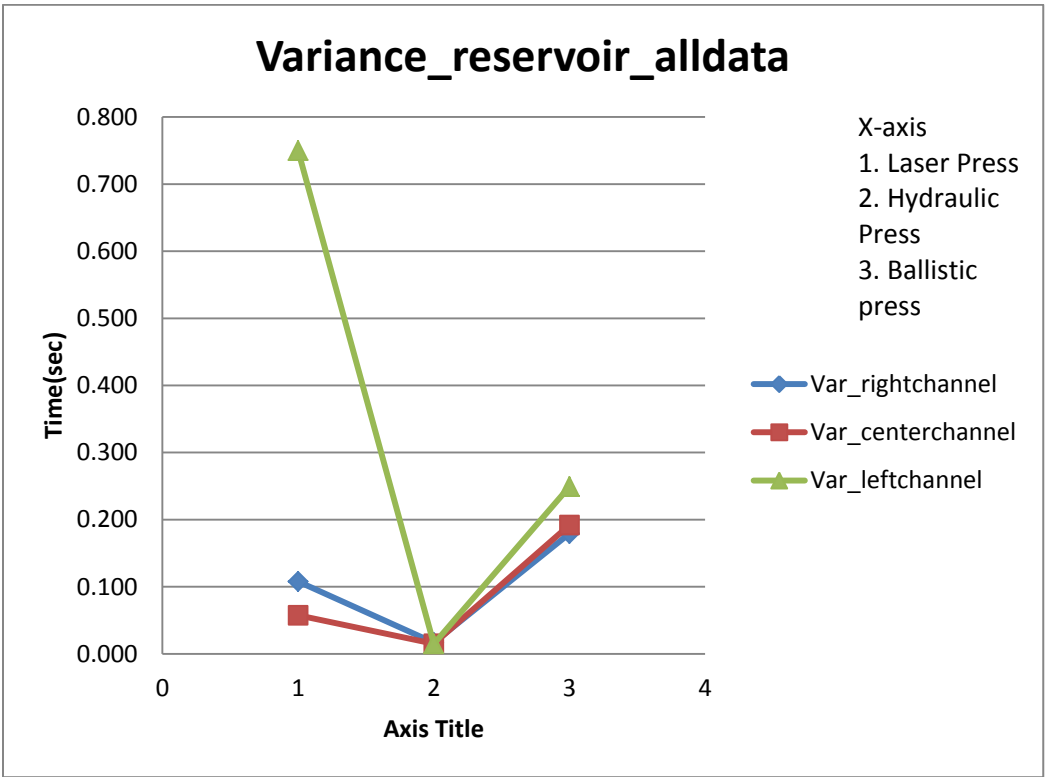
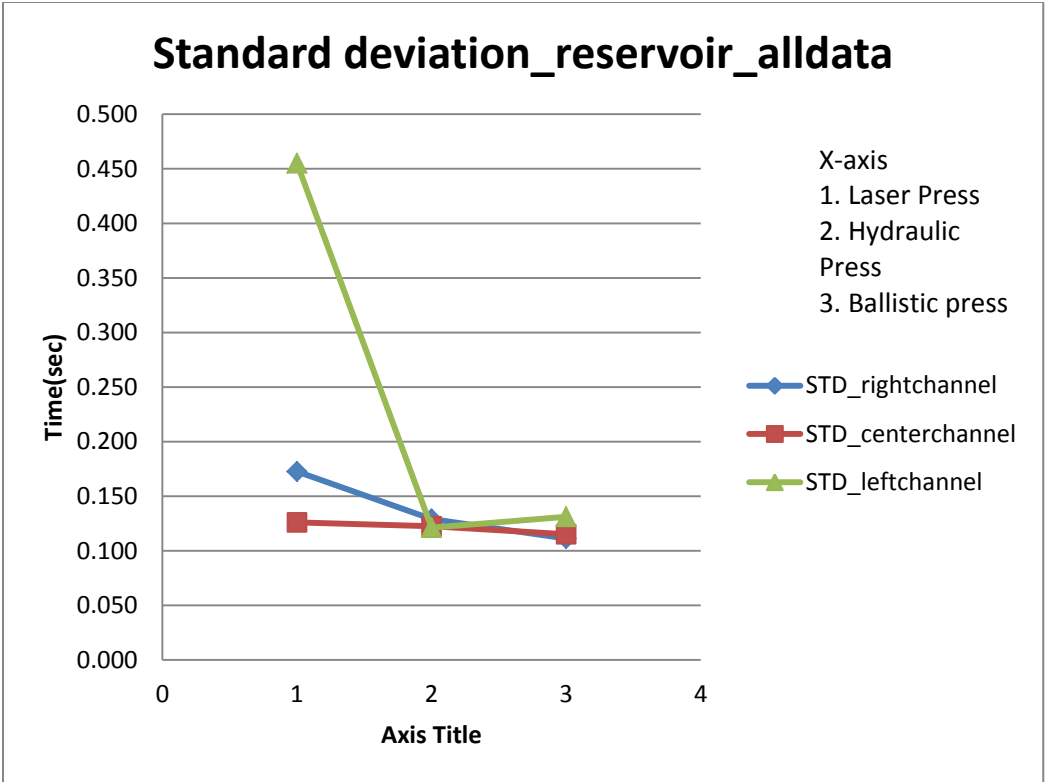
Ballistic Press

Flow time for Ballistic Press			
	Right channel (Inclined)	Center Channel	Left Channel (Perpendicular)
	Reservoir B-C (s)	Reservoir B-C (s)	Reservoir B-C (s)
Mean	3.190	3.240	3.355
Standard deviation	0.111	0.115	0.131
Variance	0.179	0.192	0.249

The data shown in the table includes all the channels with the defects the charts representing the data are shown as follows.

Figure-49





The charts above show the mean, standard deviation and variance of the flow duration using whole milk as a fluid the charts shows all the data including defects.

The data without any defects included are shown below.

Table-20.

Laser Press

Flow time for Laser Press			
	Right channel (Inclined)	Center Channel	Left Channel (Perpendicular)
	Reservoir B-C (s)	Reservoir B-C (s)	Reservoir B-C (s)
Mean	2.880	3.010	3.052
Standard deviation	0.138	0.117	0.457
Variance	0.069	0.757	0.757

Table-21

Hydraulic Press

Flow time for Hydraulic Press			
	Right channel (Inclined)	Center Channel	Left Channel (Perpendicular)
	Reservoir B-C (s)	Reservoir B-C (s)	Reservoir B-C (s)
Mean	3.452	3.521	3.645
Standard deviation	0.130	0.116	0.105
Variance	0.017	0.013	0.011

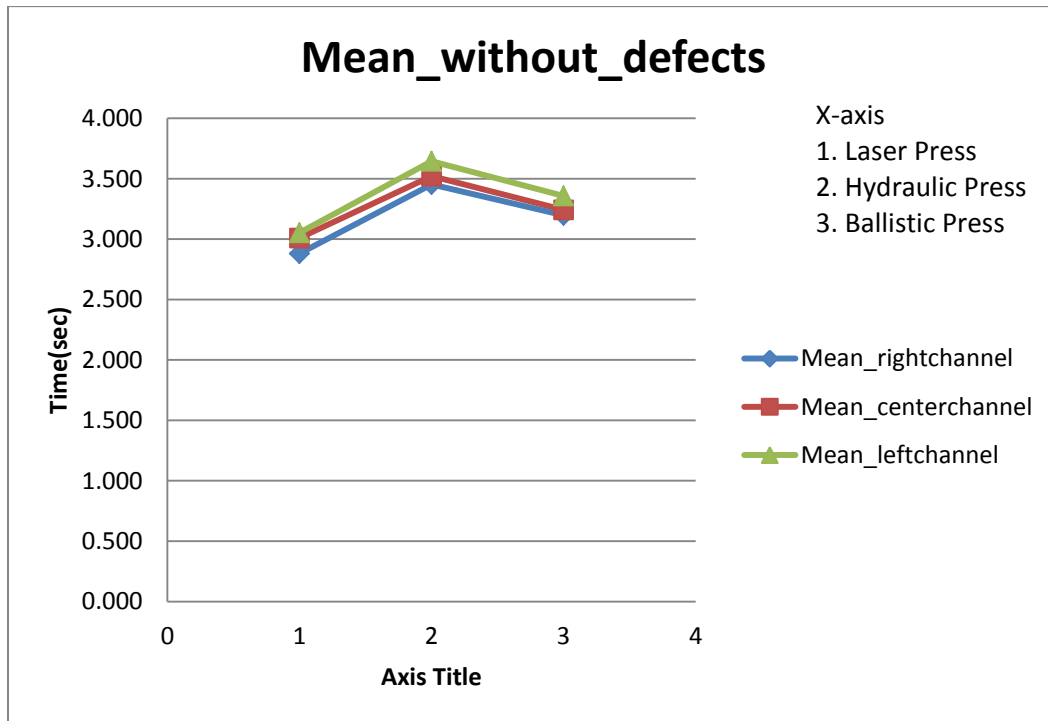
Table-22

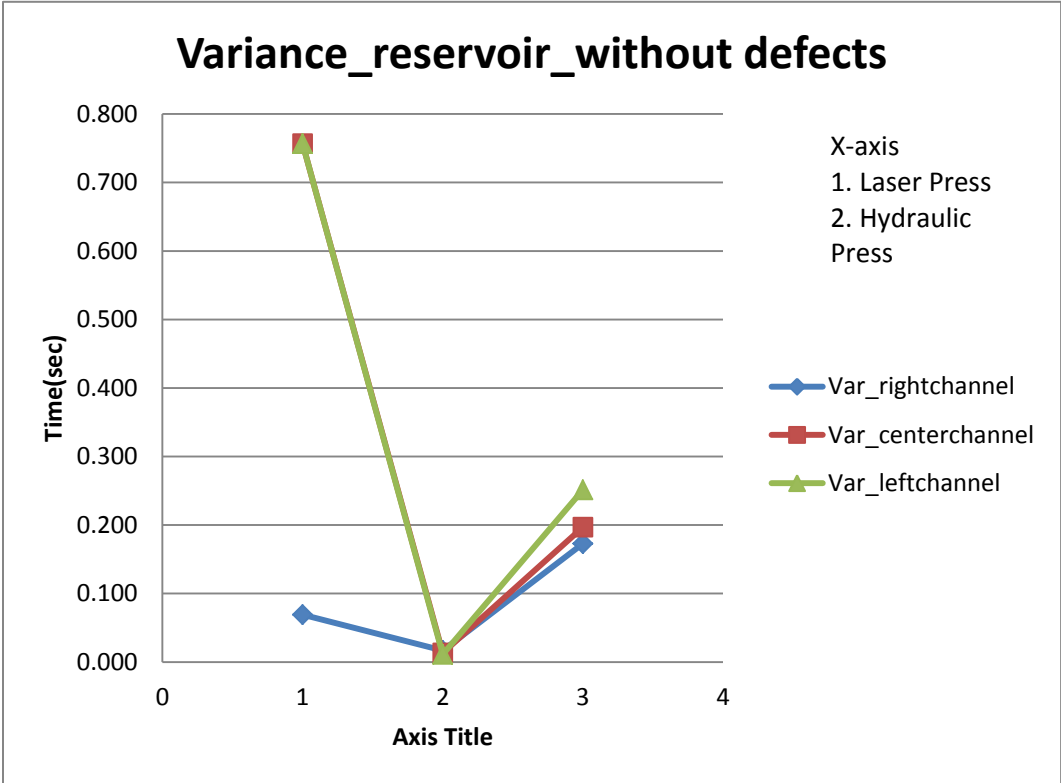
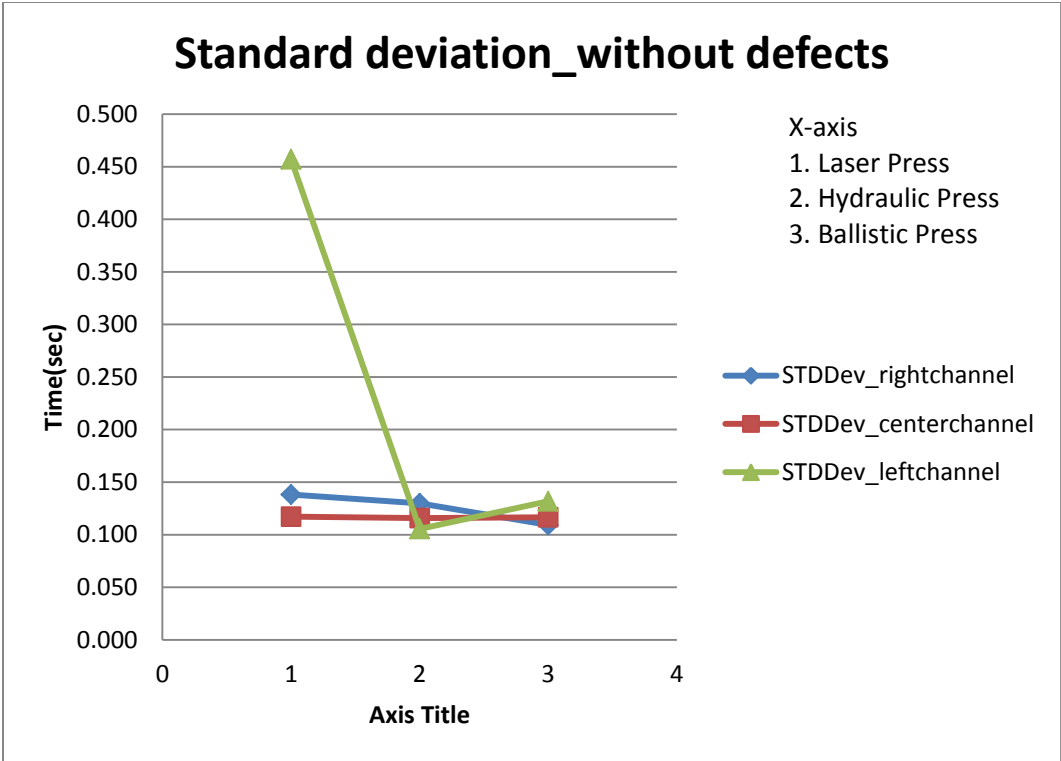
Ballistic Press

Flow time for Ballistic Press			
	Right channel (Inclined)	Center Channel	Left Channel (Perpendicular)
	Reservoir B-C (s)	Reservoir B-C (s)	Reservoir B-C (s)
Mean	3.197	3.243	3.358
Standard deviation	0.109	0.117	0.132
Variance	0.173	0.197	0.251

The data shown in the table includes all the channels without the defects the charts representing the data ar shown as follows.

Figure-50





The charts above show the mean, standard deviation and variance of the flow duration using whole milk as a fluid the charts shows data without defects included.

It is observed that the data with or without any defects in this sample don not affect the flow duration largely, there is a very minimum effect on the flow duration by removing defects unlike observed in a different sample set tested earlier with whole milk as well as the water based dye as fluid. This error could be incorporated due to the manufacturing process of the press.

The experiment as mentioned earlier was carried out on another set of single channel samples, the rotary press, stamped press and laser press, The whole milk which was used as fluid was introduced in the samples using a pippete, the sample was placed against a red background and the images were captured at 420 fps, the images were then analyzed to obtain the flow duration and for any defects, the data showing the flow duration for the samples are shown in the table below.

The data shown in the table shows all the data included with the defects the flow duration is calculated as shown in the image below.

Figure-51.



Table-23

Rotary sample

Flow time for single channel Rotary press		
	Single channel	
	Reservoir (B - C) (s)	Channel (A - C) (s)
Mean	1.935368	3.923358
Standard deviation	0.117605	0.169876
Variance	0.025039	0.052243

Table-24

Stamped sample

Flow time for single channel stamped press		
	Single channel	
	Reservoir (B to C) (s)	Channel (A to C) (s)
Mean	2.22406	4.131955
Standard deviation	0.16206	0.192926
Variance	0.380368	0.539056

Table-25

Laser sample

Flow time for single channel laser press		
	Single channel	
	Reservoir (B to C) (s)	Channel (A to C) (s)
Mean	2.209524	4.215539
Standard deviation	0.14	0.168305
Variance	0.283862	0.410248

The data without any defects included for the above single channel data is shown in the table below.

Table-26.

Rotary sample

Flow time for single channel Rotary press		
	Single channel	
	Reservoir (B to C) (s)	Channel (A to C) (s)
Mean	1.940	3.930
Standard deviation	0.121	0.184
Variance	0.027	0.061

Table-27

Stamped sample

Flow time for single channel stamped press		
	Single channel	
	Reservoir (B to C) (s)	Channel (A to C) (s)
Mean	2.221	4.128
Standard deviation	0.162	0.192
Variance	0.378	0.534

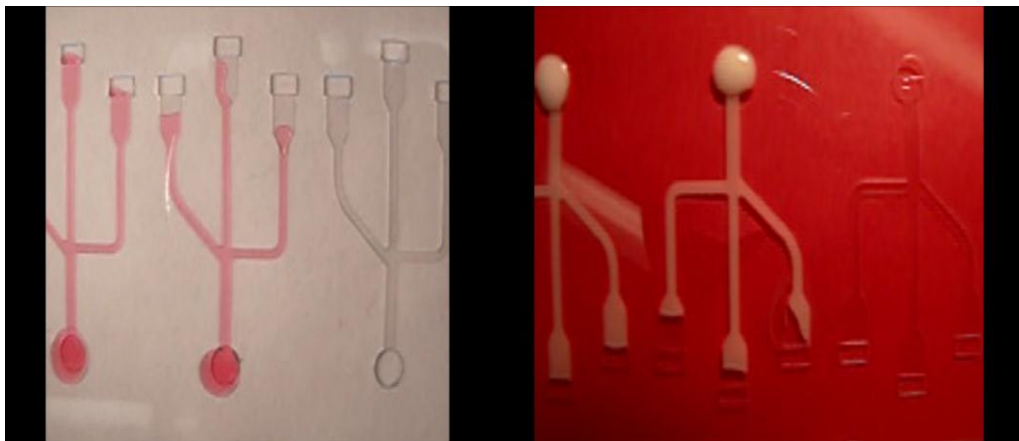
Table-28

Laser sample

Flow time for single channel laser press		
	Single channel	
	Reservoir (B to C) (s)	Channel (A to C) (s)
Mean	2.214	4.216
Standard deviation	0.139	0.167
Variance	0.280	0.402

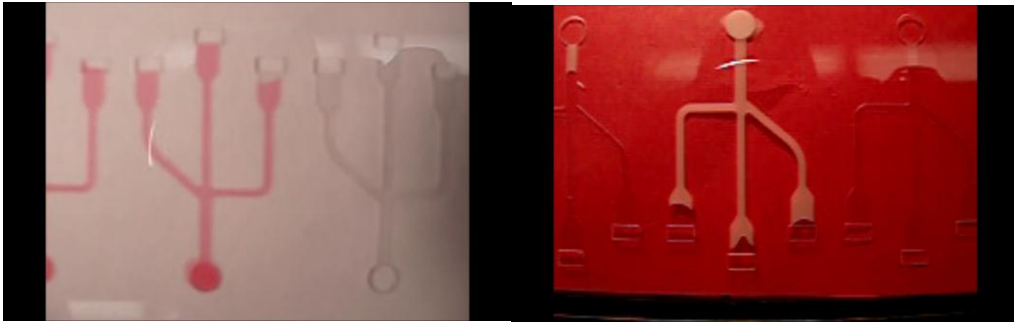
The defects observed during testing all the samples are substantial, there were many defects observed in the three channel Ballistic, Hydraulic and Laser press. The number of defects and some of the defects observed in the press are shown below.

Figure-52



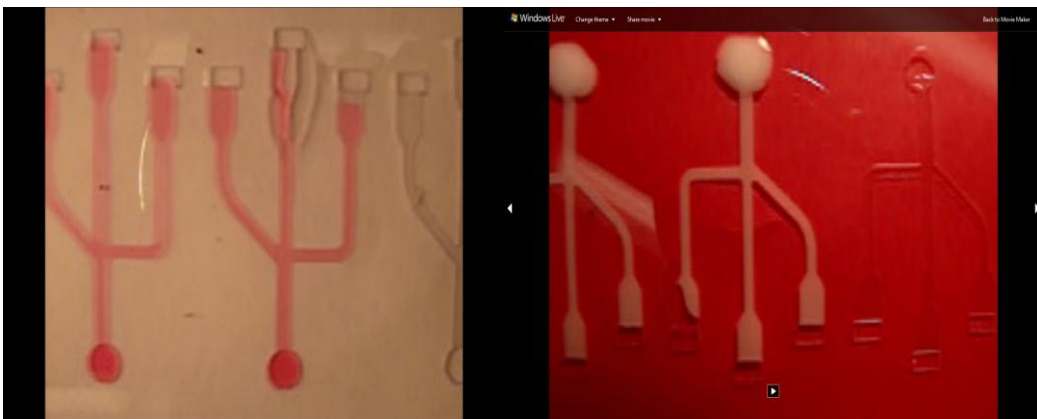
Defects observed in ballistic press using water based dye and whole milk as fluid.

Figure-53



Defects observed in Hydraulic press using water based dye and whole milk as fluid.

Figure-54



Defects observed in Laser press using water based dye and whole milk as fluid.

Table-29.

Defects Observed in Dye as fluid

Press\Channel	Right		Center		Left	
	Reservoir	Channel	Reservoir	Channel	Reservoir	Channel
Ballistic	2	0	5	0	3	0
Hydraulic	5	0	4	0	5	0
Laser	3	0	4	0	5	0

Table-30

Defects Observed in whole milk as fluid

Press\Channel	Right		Center		Left	
	Reservoir	Channel	Reservoir	Channel	Reservoir	Channel
Ballistic	4	0	3	0	1	0
Hydraulic	3	0	3	0	2	0
Laser	2	0	3	1	3	0

The defects observed when the three channel samples were projected on to a screen using a laser is as shown below.

Table-31

Press\Channel	left	center	right
hydraulic set1	3	1	2
hydraulic set 2	1	0	1
hydraulic set3	0	1	0
ballistic set1	0	0	1
ballistic set2	1	1	1
ballistic set3	0	0	0
laser set1	0	0	1
laser set2	0	0	0
laser set3	0	0	1
Laser Set 4	1	1	1

The table above shows the number of defects observed in each channel. Each set contains-10 samples each.

Defects observed in a single channel are shown and tabulated below.

Table-32

Press\Channel	Description	
	Reservoir	Stem
Stamped	1	0
Rotary	2	1

The defects observed are flow defects and also defects due to manufacturing of the press.

The flow profile in the reservoir was observed to be flat throughout the experiment however there were certain samples where the flow profiles were observed to be parabolic in nature. To better understand the flow profile in the reservoir the meniscus of the flow profile are calculated by taking a reference point along the midpoint of the reservoir and calculating the distance between the reference point and the walls of the reservoir. Three reference points along both the left wall and right wall are taken and the distance is referenced along with three reference points along the center of the reservoir. The data was collected for whole milk as fluid and are as shown below in the table

Table-33

Mean(Left wall)	Perpendicular	Centre	Inclined
Hydraulic	0.849333333	1.152666667	0.872666667
Laser	-0.319375	-0.00875	-0.245
Ballistic	0.308	0.324333333	0.177333333
Mean(Right wall)			
Hydraulic	0.485333333	0.798	0.807333333
Laser	0.196875	0.142625	0.126875
Ballistic	0.065333333	0.153	0.252

Table shows the mean distance for both the left wall and the right wall. All dimensions are in mm.

Table-34

Standard Deviation (Left wall)	Perpendicular	Centre	Inclined
Hydraulic	0.506366921	0.943072193	1.002490201
Laser	0.788998215	0.345666918	0.708994041
Ballistic	0.358820085	0.402626244	0.355597542
Standard Deviation (Right wall)			
Hydraulic	0.364617884	1.028443081	1.022719688
Laser	0.559768158	0.429871457	0.62590689
Ballistic	0.432077966	0.317168804	0.298170491

Table shows the Standard deviation for both the left wall and the right wall. All dimensions are in mm.

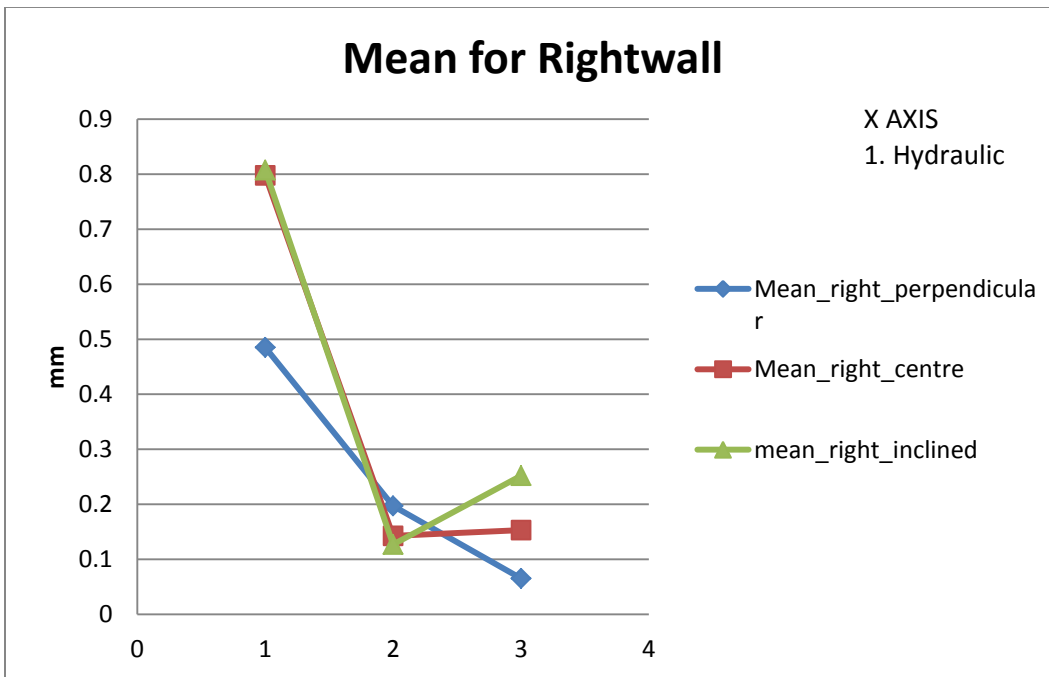
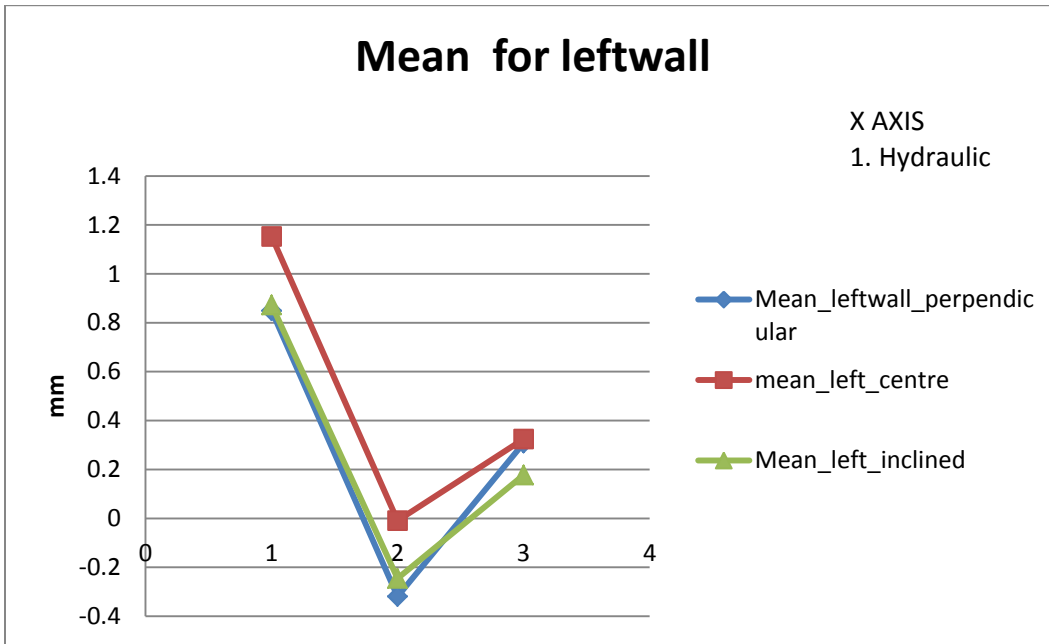
Table-35

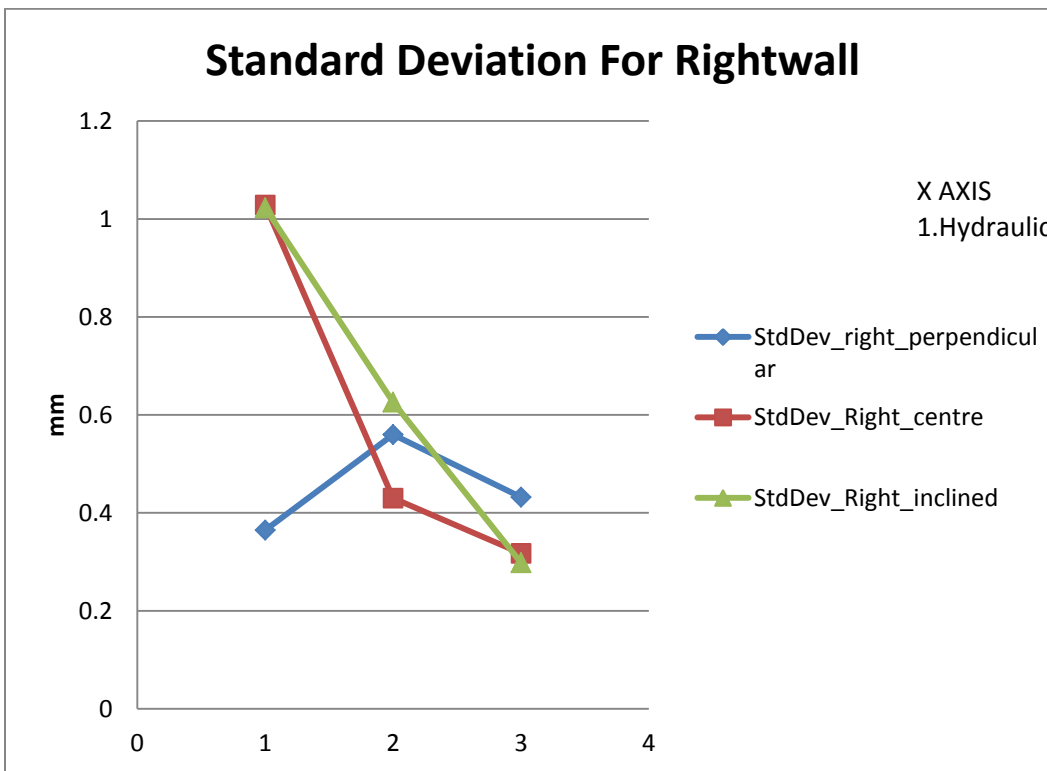
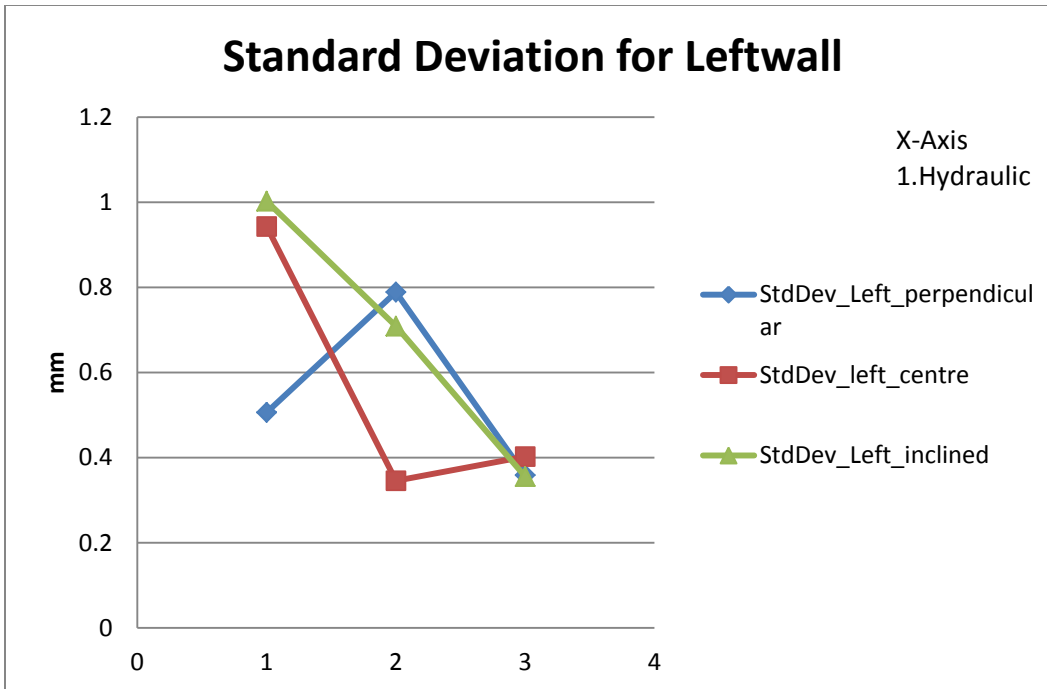
Mean of $\Delta R/\Delta L$	Perpendicular	Centre	Inclined
Hydraulic	0.891053391	0.672407407	0.583730159
Laser	-0.021428571	0.540909091	0.032921811
Ballistic	0.296666667	0.240384615	0.181818182

Table shows the ratio $\Delta R/\Delta L$ for both the left wall and the right wall. All dimensions are in mm.

The data collected above are as shown in the plot below.

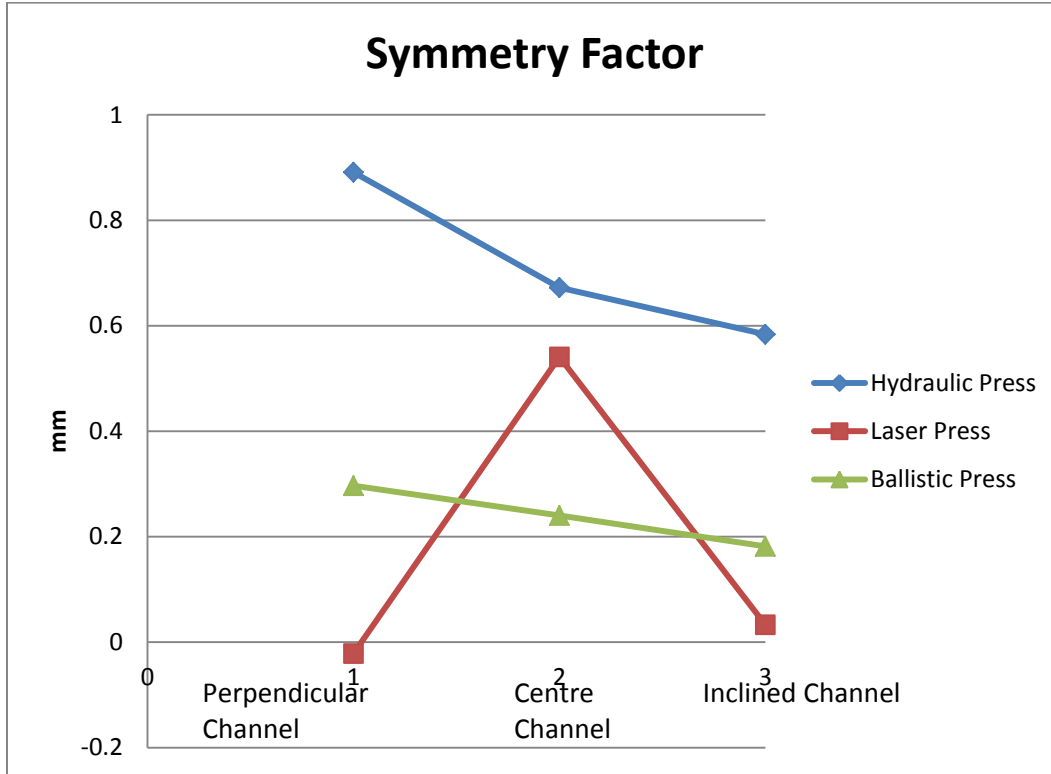
Figure-55





Figures showing the mean and the standard deviation for the reservoir. All dimensions are in (mm) and the fluid used is whole milk.

Figure-56



Ratio of lengths for the right wall and left wall.

The Symmetry factor shows the lead or lag with reference to the center reference point. If the value is negative the fluid is lagging if the value is positive it refers to fluid leading with respect to reference point.

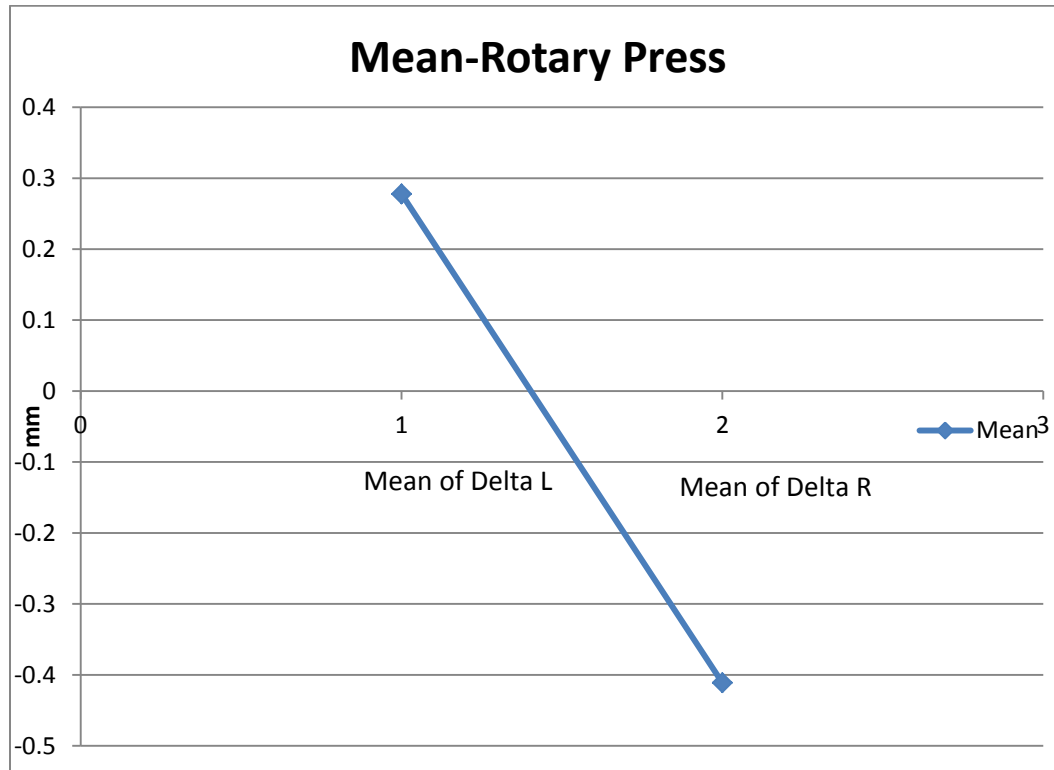
The data for single channel reservoir analyzing the distance from the center reference point to the left and right wall for both the rotary and stamped press are as shown below.

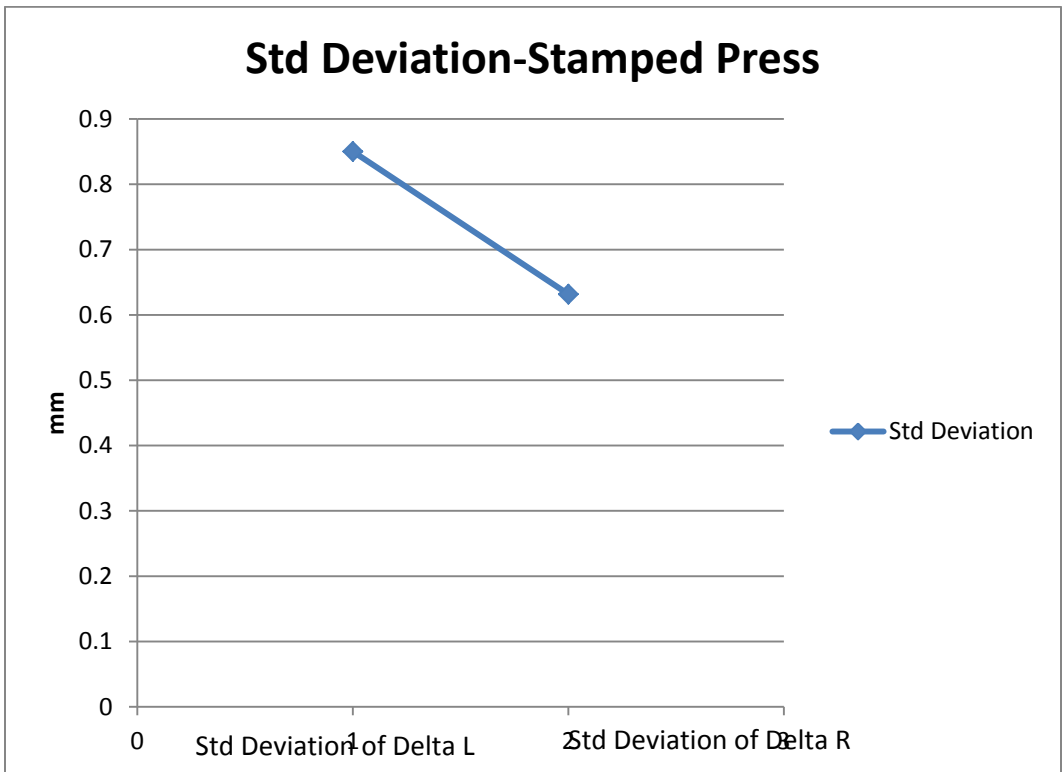
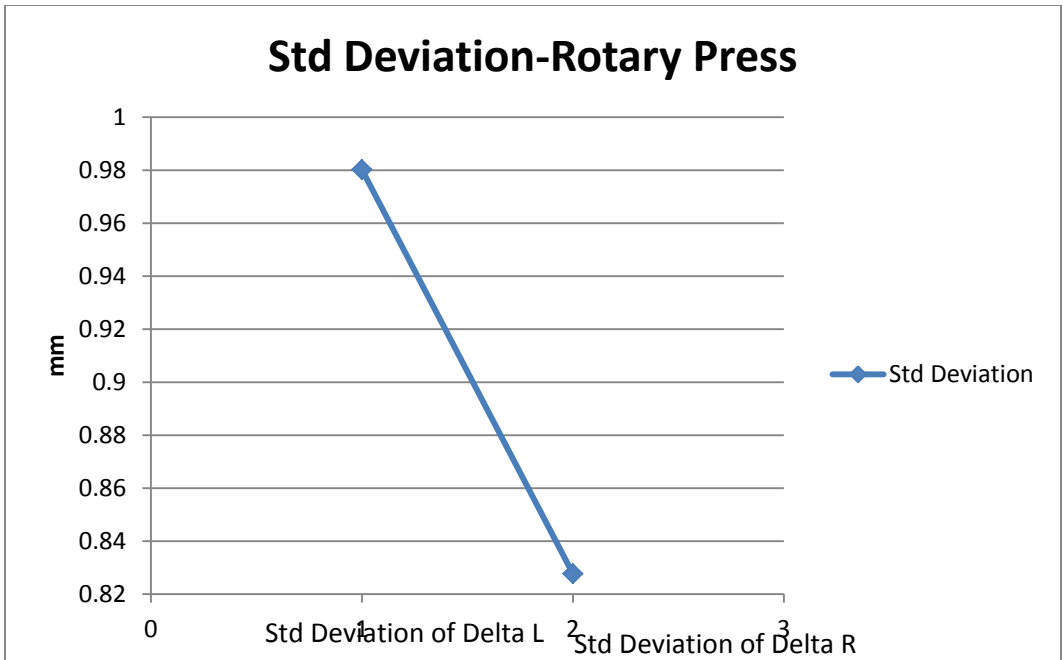
Table-36

		Left wall	Right wall	$\Delta R/\Delta L$
Rotary press	Mean	0.277778	-0.411111	-0.09405
	Standard Deviation	0.980234	0.827708	
Stamped press	Mean	0.270833	-0.125	-0.27899
	Standard Deviation	0.850271	0.631614	

Data for stamped and rotary press.

Figure-57





Mean and Standard deviation plots for rotary and stamped press for whole milk as fluid.

Chapter 5

THEORETICAL MODEL OF A FLUID FLOWING IN THE RECTANGULAR CHANNEL.

5.1 Theoretical model of fluid flowing in the rectangular channel.

Dimension of the channel are assumed to be 1mm x 2mm x 100microns (W x L x H).

Reynolds number is calculated to determine the nature of flow whether laminar or turbulent.

$$Re = \rho VL/\mu$$

Assuming, steady incompressible, laminar flow. The flow is in the X-direction hence no velocity component in the Y or Z direction. For steady state and incompressible flow we have the continuity equation

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

Where u, v and w are the velocity components in the x, y and z direction.

Since there is no velocity component in the Y and Z direction we get

$$\frac{\partial u}{\partial x} = 0$$

Since the height z is very small the velocity component u is a function of y alone

The velocity u is a function of y and z .

$$u = u(y, z)$$

The flow in the channel is affected by the friction at the walls. The flow in the channel is driven by the viscous force. The force due to viscosity is calculated by using the following equation.

$$f_v = -\mu A \frac{\partial u}{\partial x}$$

The frictional force at the walls is obtained by using the following expression

$$f_f = \mu_f (w)$$

Where w is the average weight of the fluid acting on the wall and μ_f is the coefficient of friction of the material.

The difference between the viscous force and the frictional force at the wall determines the flow profiles on the fluid. Two conditions apply to this particular case one if the difference of the viscous force is more than the frictional force and second if the viscous force is less than the frictional force, as in the latter case the frictional force being more than the viscous force implies the velocity at the walls is zero. The velocity profile for the particular case is as describe below.

Velocity profile for frictional force being more than the viscous force, applying the boundary conditions for $y = \pm h$ and $u = 0$,

Applying the Navier-Stokes equation we get

$$\frac{\partial p}{\partial x} = \mu \frac{d^2 u}{dy^2} \quad 1$$

$$\frac{\partial p}{\partial y} = -\rho g \quad 2$$

$$\frac{\partial p}{\partial z} = 0 \quad 3$$

The velocity profile is obtained by integrating the equation 1 twice.

$$u = \frac{1}{2\mu} \frac{\partial p}{\partial x} (y^2 - h^2)$$

The velocity profile represents a parabola.

The velocity profile for the viscous force being more than the frictional force is as discussed below.

The boundary conditions $y = \pm h$ and $u = v_w$, where v_w is the velocity at the wall.

Applying the Navier-Stokes equation, from equation 1 we get.

$$v_s = \frac{1}{2\mu} \frac{\partial p}{\partial x} + c_1 h + c_2$$

Solving for c_1, c_2 we get the velocity profile as

$$u = v_s + \frac{1}{2\mu} \frac{\partial p}{\partial x} (y^2 - h^2)$$

The flow observed in this case is due to the viscous force which can be calculated by using

The drag coefficient is calculated by $f_v = \frac{1}{2} C_d \rho V^2$.

Chapter 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion.

This document discusses the image processing model, design and selection of lens, functions used in the preprocess and enhancement of image processing, image processing applied in satellite image data and weather monitoring.

An experimental setup and procedure describing the image processing in environmental monitoring and Image analysis of fluid such as water based dye and whole milk flowing through a microchannel. Image processing in environmental monitoring involves the analysis of level of water flowing through a canal. The images are captured using a scientific digital camera, the images are stored onto a datalogger, the images are retrieved using a cellular and satellite modem using a image retrieval software. The images retrieved are processed using MATLAB software, the contrast of the image is adjusted using image enhancement function known as contrast stretching. The contrast adjusted images are used to obtain the level of water by plotting pixel intensity values along three vectors from top of the scale to the end of the scale. The intensity plots are converted to ft. using image scaling. Three separate intensity plots are taken, the average level of water is determined from the intensity plots. The level of water flowing through the canal throughout the day is archived and plotted to show the variation in the level of water throughout the day.

High speed image analysis was performed to determine the flow through a micro channel, the samples tested were manufactured using different techniques namely Ballistic press, Hydraulic press, Laser press, Rotary and stamped press. The first three types of presses being a three channel press and the latter two being a single channel press. The high speed image data was obtained by placing the samples in a well illuminated and suitable contrast background. The fluid used which was water based dye and whole milk was introduced into the channel using a pipette, the image data obtained was then analyzed for flow duration and observed for any defects in the due course of analyzing. The data obtained was tabulated. The defective samples were marked for further analyzing using a scanning electron microscope. To better understand the flow pattern an alternate experimental setup was prepared where the images are projected onto a screen using a laser beam. The samples are placed on a mounting plate and a laser beam is focussed onto the samples, the projected image is then captured using the high speed camera, the image data obtained was again analyzed for flow duration and defects again the defects observed are marked for further analyzing using SEM.

6.2 Recommendation.

The images obtained was of very low resolution, a better resolution camera could be used to obtain images to simplify the image analysis process. Environmental monitoring can be carried out at different locations such as rivers and other water bodies enabling the monitoring the level of water and providing a visual image of

the conditions at the site. Further research is being carried out on the river head to monitor the level of water and the conditions at the site.

The high speed imaging analysis in micro channels can be enhanced by using advanced high speed imaging cameras and image retrieval devices. The flow in microchannels can be tested with more viscous fluids this will enhance the analysis of defects in the channel. Analyzing the defects with SEM should give a better insight into the defects observed in the channels and reduce the number of defects observed in samples.

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