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STUDY ON TWO STAGE AUTHENTICATION FOR ONLINE TRANSACTION IN MOBILE DEVICES

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ABSTRACT

In recent years with remarkable development in technology, single factor authentication e.g., passwords are no longer considered secure. The widespread adoption of online financial transactions has raised concerns about the security of digital payment systems. Multi-factor authentication is a security mechanism that entails employing additional techniques in addition to the usual login and password to verify a user's identity. The use of two stage authentication has emerged as a critical security technique to reduce the risks of unauthorized access and fraudulent activities. This paper looks at how two stage authentications might improve the safety of online financial transactions. The paper examines the efficacy of two stage authentication in avoiding unauthorized access and financial fraud through a thorough analysis of recent literature and case studies. It explores numerous two stage authentication techniques, highlighting their advantages and disadvantages. These techniques include SMS-based codes, biometric verification, and hardware tokens. To overcome the shortcomings of the existing technique, we proposed a system that includes fingerprint authentication along with PIN at the time of money transaction to avoid unauthorized access.

Keywords: Two Stage Authentication, Online Transaction, Mobile Banking, PIN, Transaction Security, Fingerprint Authentication, Bio metrics, Internet Banking

1 INTRODUCTION

The emergence of the digital age has fundamentally changed how we carry out financial transactions. Our everyday lives have become completely reliant on online banking, e-commerce, and mobile payment apps, which provide unmatched ease. In this context, the security of financial transactions is of paramount importance. Financial data, personal information, and transactions themselves are prime targets for malicious actors seeking to exploit vulnerabilities in the digital ecosystem. To protect against these attacks, two stage authentication is a crucial protection measure. Users are required to supply two separate factors—typically something they know, like a password, and something they have, like a mobile device—to confirm their identity when using two stage authentication These elements working together considerably improve security by lowering the possibility of unwanted entry. Two stage authentication is a crucial tool for safeguarding the confidentiality, integrity, and authenticity of financial data since it makes it harder for hostile actors to access financial accounts. The growing concerns regarding the vulnerability of financial data and personal information in the digital space is the motivation behind this research work.

Utilizing a secret password is the most popular method of user authentication. The password is, however, susceptible to different cyber-attacks. Therefore, it becomes vital to secure sensitive information of online transactions in mobile devices. The paper [11] discusses identity theft and prevention against it. Identity theft poses a significant and genuine threat to everyone. By using two stage authentications with random codes, the Secure Online Transaction Algorithm (SOTA) seeks to address this. SOTA utilizes mobile devices and an application for logging into card accounts, generating unique codes. This approach significantly reduces the risk of unauthorized users exploiting someone else's information for fraudulent activities. A robust approach for authentication in mobile banking involves integrating user ID and password with fingerprint recognition is discussed in paper [8]. Increased dependability is provided by this combination approach, guaranteeing safe access to private financial data and transactions. The paper [11] introduces a segment-based online signature verification approach for

securing mobile transactions. It identifies invariant segments in a user's signature, leveraging touch screen data to extract geometric layout and behavioral characteristics. Additionally, it employs a quality score during enrollment for robust user signature profile construction, ensuring reliable verification despite geometric distortions on touch screens.

Paper [10] explains the implementation of facial recognition techniques for login and banking purposes which is aimed at enhancing security measures. The proposed system uses a multi-level approach, integrating traditional username and password verification with advanced facial recognition capabilities. Additionally, users are required to input a PIN to successfully complete the transaction process. The solution delivers a strong and trustworthy security framework, protecting sensitive financial data, and preventing unwanted access by utilizing these combined authentication techniques. Paper [9] explains the value of Virtual Private Networks (VPNs) for gaining access to data resources on cloud servers. It suggests a unique architecture with a Multi-Factor Authentication (MFA) system to boost security by using biometrics and low-entropy passwords. Mobile devices, authentication servers, and banking servers are some of the components of the suggested model. It makes use of voice recognition as a crucial factor in authentication. The effectiveness and efficiency of the system is analyzed, and it is found to be protected against various attacks. The proposed system can improve the security functions by protecting the credentials in the database of the authentication server. The Paper [3] discusses the increasing number of ATM users and the associated security risks, particularly the threat of financial losses due to stolen ATM cards and PINs. It emphasizes the advantages of biometric technology, with a focus on fingerprint recognition, as a more secure and efficient means of authentication. Fingerprint recognition is highlighted for its simplicity, non-stored image data, and resistance to misuse, making it a promising solution to enhance ATM security and protect users from potentially fraudulent activities. Fraud attacking the automated teller machine (ATM) has increased over the decade. The Paper [3, 7] describes a system that replaces the ATM cards and PINs by the physiological biometric fingerprint and iris authentication. The Socket Secure version 5 (SOCKS V5) protocol describes the password-based authentication to provide authentication services to the initial SOCKS protocol. In this system, the request transmits the password in simple text and thus, it is not recommended due to security reasons. In this paper, we proposed a two-stage authentication system that uses fingerprints along with PIN to enable online payments. The primary objective of this paper is to fortify security measures by implementing a robust two stage authentication system, thereby reducing the risk of unauthorized access, and safeguarding sensitive information. The paper aims to prioritize user experience by adopting user-friendly two stage authentication methods, ensuring minimal user inconvenience. The paper recognizes the critical necessity of reinforcing the security of online transactions, particularly with regards to the protection of sensitive financial data and the prevention of unauthorized access.
The remaining paper is arranged as follows: We will first go through the existing technique on two factor authentication in Section 2. Then we will discuss the enhancement of the existing system in Section 3. After that we will describe our proposed model in Section 4. Section 5 deals with the future scope of the two-stage authentication. At the end we will conclude our work in Section 6.

2 EXISTING TECHNIQUE

In conventional systems, system resources are available for a predetermined amount of time or until the user logs out explicitly once their identification has been confirmed. which assumes that the user's identification remains unchanged for the duration of the session and that a single verification at the start of the session is sufficient.

In existing system [11], the authors proposed a technique using two stage authentications along with One-Time Password. This framework utilizes a smartphone application that is registered to a specific credit card. The code needed to authenticate the purchase the customer is trying to make will be sent via the application, which will act as the transmission device. The consumer's purchase is validated and confirmed if they enter the correct code, else the transaction will be rejected. After choosing the desired product, the consumer proceeds to checkout. If they choose a credit card secured with this framework, the Online Retailer Employs Public Key Infrastructure Advanced Encryption Standard (PKI AES) Encryption to securely transmit consumer data to the Credit Card Company. Upon verification, the Credit Card Company utilizes Secure Hash Algorithm (SHA-256 hash) to send an eight-digit number to the Online Retailer and a corresponding one-time password (OTP) to the consumer's credit account smartphone application via PKI. The online retailer completes the transaction if the hashed code input by the customer and the hashed code supplied to them by the credit card company match.

A strong approach for authentication in mobile banking integrating it with user ID, password, and fingerprint identification to improve security and reduce risks is explained in paper [8]. The most common biometric modality, the fingerprint, is scanned, improved, and turned into a template by a mobile device's scanner. In terms of dependability and fraud prevention, biometrics outperforms conventional techniques like PINs and passwords because it uses an individual's physiological or behavioral characteristics for automatic identification. The money will be sent to the appropriate categories, such as Net Banking, Credit Card Payment, and Wallet, upon successful fingerprint authentication.

In paper [12], signature verification is used for securing mobile transactions. The proposed system normalizes signatures by generating concentric circles (R1 and R2) to establish scaling, constraining signature coordinates to [-1, 1]. Normalized signatures are interpolated to ensure uniform length. The feature extraction component captures geometric layout and user characteristics. Signature quality evaluation yields a score balancing inconsistency and distinctiveness for user profile construction. Critical segment extraction identifies stable feature segments reflecting intrinsic signing behaviors. Utilizing the similarity score, our system determines acceptance or rejection of the user.

Paper [9], proposed a model that comprises a mobile device, authentication server, banking server, and users with valid low entropy passwords and biometric identities. Its scalability allows for multiple users and banking servers. User accesses Banking server by registering a low entropy password and unique biometric identity, especially their distinct voice. Users initially register with the authentication server using a low entropy password and International Mobile Subscriber Identity (IMSI) number, while biometric users generate a key pair for registration. The authentication server verifies the digital signature and IMSI, granting a ticket to the user, facilitating communication with the banking server. During authentication, the user provides the low entropy password and unique voice, verifying identity. The user's password undergoes an authentication check, prompting the user device to send a login message to the authentication server. Upon successful verification, the authentication server grants a session key, ensuring secure user access to the Banking server.

A facial recognition system is a technological tool that can compare a digital image or video frame containing a human face to a database of faces. An approach using facial authentication is explained in paper [10]. The face authentication system operates in three stages: image acquisition, model training, and recognition. Image acquisition requires high-quality images for effective face detection and recognition. For each user, 100 images of 136×136 pixels are acquired via a webcam and converted to grayscale, separating the luminance from the chrominance planes. These images are then transformed into matrices and labeled accordingly. A Local Binary Pattern Histogram (LBPH) face recognizer model is created, trained with the image matrices and their corresponding labels, and saved during the process. Face recognition involves the use of the Haar cascade classifier and the trained recognizer. If the confidence scores meet the set criteria, the user is authenticated; otherwise, they are classified as unknown. Python, along with the OpenCV library, is employed for the face recognition system, while MySQL is utilized for the bank record management.

Paper [3], proposed a system which integrates fingerprint into ATM alongside PIN numbers. Using this framework, users can feel at ease knowing that their accounts are safe from unauthorized access. After fingerprint verification, a specialized fingerprint module generates a 4-digit code which is sent to the user's registered mobile number. Customers are guaranteed additional security measures during ATM transactions because access is authorized based on the validation of this code.

A Two Factor Authentication channel based on steganography in the QR code is proposed in [2]. The main technique used is steganography, specifically steganographic insertion and extraction, to hide mTAN in QR codes. Additionally, AES encryption ensures the security of mTAN during transmission. This combination of techniques is intended to enhance the security of the 2FA system.

In Paper [6] a new authentication protocol that could be used on mobile devices allowing more secure authentication between mobile users and SOCKS proxy server is proposed. In addition, authentication is also provided between SOCKS proxy server and application server. Furthermore, the proposed protocol also generates secure session keys between mobile user and proxy server, and proxy server and application server.

Paper [1] doesn't specifically highlight the technology used in the research. However, it can be inferred that the technology used for data collection and analysis includes data extraction from publicly available sources, as well as tools and software for assessing the compliance, robustness, and complexity of MFA protocols. The research likely utilized various cybersecurity and analytical tools for assessing MFA security and complexity.

Paper [4] presents a comprehensive analysis of authentication techniques, encompassing single-factor and multi-factor methods. Notably, the study reveals that smart card-based authentication stands out as the most extensively researched single-factor technique. Furthermore, the combination of text passwords and smart cards emerges as the most investigated approach in multi-factor authentication. The research underscores the paramount criteria for evaluating and selecting authentication schemes, which primarily include usability, security, and cost-effectiveness. This systematic review underscores the extensive research efforts in the domain of authentication while highlighting the need for further exploration in various application contexts.

In paper [5], a two-level integrated authentication mechanism (2L-IAM) was proposed. At the first level, the user will be authenticated using their fingerprint or personal identification number, and at the second level, face recognition (FR) will be used to authenticate them. The justification for the suggested 2L-IAM is that FR-based second level authentication ensures the genuine identification of the authorized IB user.

3 ENHANCEMENTS OF EXISTING TECHNIQUE

As technology advances, so do cyber criminals' strategies. Report shows that nearly 15 billion credentials were taken from 1000000 data breaches. Possessing these credentials, fraudsters can access medical records, bank accounts, trade secrets of companies, and much more. This shows that the existing system and username and password combination is liable to risk.

In paper [11], during transmission, if one bit is changed, then the hashed data will not match the other hashed data. This, in turn, will not authenticate the user and will prevent the purchase from being completed. Besides this, credit card companies will have to pay a certain amount to adopt this approach. Facial authentication that is used in [10] is subject to facial spoofing which means a fraudster may attempt to bypass a facial authentication system by presenting a false image.

The implementation of steganography in the QR-code for two factor authentication [2] can be complex and may require specific software. The adoption of this technique by users and organizations may require time and effort.

To overcome all the drawbacks of the above-mentioned system, we proposed a system using fingerprint to authenticate the user. At the time of payment, the user is required to enter PIN and authenticate the fingerprint to make the payment.

In Paper [1] there are some parameters, Comprehensive Evaluation: The research provides a detailed evaluation of MFA solutions in online banking by considering multiple criteria, including compliance, security, and usability. Global Perspective: The study covers banks from different countries, offering a global perspective on the state of MFA adoption in the banking sector. Novel Complexity Metric: The introduction of a novel metric to assess the complexity of MFA protocols provides a unique contribution to the field. Regulatory Impact: The research identifies the potential influence of regulations, like the Regulatory Technical Standard (RTS), on improving the security of MFA protocols in online banking.

In Paper [4] the researchers conducted a comprehensive analysis of various authentication techniques. Their study revealed that single-factor authentication methods are diverse, with smart card-based authentication being the most extensively researched. Furthermore, the study found that multi-factor authentication techniques often combine different single-factor methods, and the combination of text-passwords and smart cards emerged as the most widely studied approach. When comparing and selecting authentication schemes, the researchers noted that usability, security, costs, and contextual factors played pivotal roles. Notably, the research identified a gap in the existing literature as no framework was found that provided an in-depth analysis of both single-factor and multi-factor authentication techniques for decision-making processes.

To overcome all the drawbacks of the above-mentioned system, we proposed a system using fingerprints to authenticate the user. At the time of payment, the user is required to enter PIN and authenticate the fingerprint to make the payment.

4 PROPOSED WORK AND ITS IMPLEMENTATION

This paper's main goal is to increase online transaction security, realizing how important it is to protect sensitive financial data and guard against illegal access. We have created a novel hybrid authentication system that combines various layers of verification throughout the transaction process to achieve this goal. This hybrid system's incorporation of both conventional and biometric authentication techniques ensures a strong and thorough approach to user verification.

4.1 REGISTRATION PROCESS

STEP 1: Open the app and enter email id and password.

STEP 2: The email id is verified by sending an OTP via mail.

STEP 3: Enter the OTP sent via email.

STEP 4: If verification fails, repeat step 1.

STEP 5: Upon successful verification, set PIN and enroll fingerprint biometric.

STEP 6: Store the information in the database.

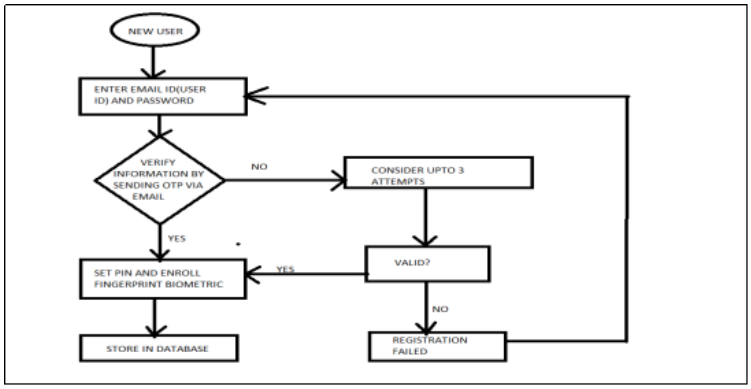

Fig. 1. User Enrollment Process

4.2 TRANSACTION PROCESS

STEP 1: Open the app and enter email id and password.

STEP 2: Choose operation.

STEP 3: For transaction, choose payee and enter the amount.

STEP 4: Next enter the PIN.

STEP 5: If valid, proceed to fingerprint authentication.

STEP 6: If PIN does not match, repeat step 3 (only 3 attempts allowed)

STEP 7: If fingerprint authentication fails, repeat step 4 (only 3 attempts allowed)

STEP 8: If fingerprint authentication is successful, the transaction will be successful.

Our hybrid approach includes a second level of protection by using fingerprint authentication which aims to enhance the security of online transactions while offering seamless and user-friendly experience. Since fingerprint patterns are unique to everyone, the user is asked to verify their identity using fingerprint authentication. The two factors process not only improves the overall security posture but also increases user trust in the transaction system.

The implementation can be done using mobile integrated development environment. Since the system depends on the built-in fingerprint sensors used in mobile phones to function, external hardware won't be required. This method uses the built-in capabilities of mobile devices to provide a simple and easily accessible solution without requiring the inclusion of new hardware. The development will be optimized for Android systems, offering a productive and easy-to-use interface. The integration of inbuilt fingerprint sensors enhances the system's security and convenience, aligning with the widespread availability of this technology in modern smartphones.

5 FUTURE SCOPE

As a future scope we are planning to implement iris recognition to our proposed system. The main reason of using iris recognition

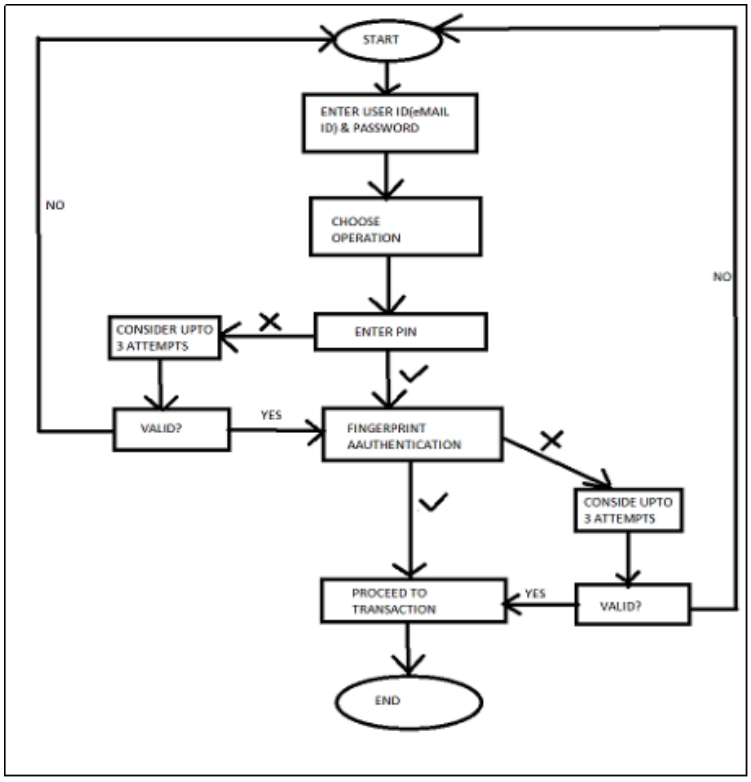

Fig. 2. Process before Transaction

is its speed of matching and extreme resistance to false matches. Besides this, we are planning to integrate it with the banking sector and create a real-time application for the industry where transactions happen instantaneously. Therefore, our goal is to make the system more trustworthy, easy to use, and safe for transferring money.

6 CONCLUSION

The implementation of a two-stage authentication system in an organization or application will represent a significant step forward in bolstering security and safeguarding sensitive information. The project is expected to successfully achieve its objectives of strengthening security by reducing the risk of unauthorized access, enhancing the user experience through user-friendly two stage authentication methods, ensuring compliance with relevant security standards and regulations, and establishing ongoing monitoring and improvement processes. The paper's success is expected to be measured by the reduced incidence of account compromises and increased user adoption. This implementation is intended to stand as a testament to our dedication to security and the protection of our organization's assets and user data.

Declaration: The authors declare no conflicts of interest.

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Data Security Perspective in Secure Data Communication

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ABSTRACT

With the enrichment of use of the internet the confidentiality and security of our information becomes vulnerable now-a-days. Security in confidential information becomes one of the key challenges in context of data leakage and unauthorised access of data. Data security is one of the main concern in recent data industry to prevent alteration and illegal access of data. To ensure utmost security researches are going on rapidly on data security aspects. Various security methods and algorithms has been introduced to protect our data. Data can be secured in multiple forms like converting the actual data into non-readable data by applying cryptography concept, Data can be hidden under any cover medium by applying stenography approaches and visual cryptography. Data can be authenticated through watermarking applications. Thus sensitive information can be protected from unauthorised access. These concepts have been introduced to satisfy main data security principles for ultimate protection.

Keywords: Data Security, Cryptography, Steganography, Watermarking, Visual Cryptography

1 INTRODUCTION

Data security become one of the challenging aspects now-a-days to protect sensitive data from misuse. Data security principles has been designed and followed to ensure security. The main aspects are Confidentiality of transferred data, Integrity of the data communication, Authenticity of the data communication medium and Non-repudiation. Confidentiality states that the information shared by users are confidential among the respective users only. No data leakage will be there among the transactions. Different cryptography techniques have been used to make sensitive information confidential[1].

Integrity ensures that the information shared in any communication are not invoked by any other than the actual users. The data should not be altered or tampered and it must be original data [1]. Authenticity provides the surety that the data received by any user transferred from an authentic source. It implies that the communication is trusted and information are generated from genuine users [1]. Non-repudiation indicates that the receiving of data could not be denied by the receiver. It basically acts as log of data sharing [1]. Data security principles deals with different aspects of secure mechanism to provide utmost security in communication medium.

2 Literature Review

Different cryptographic algorithms are discussed in paper [1] to highlight the idea of cryptography in data communication. Different key based cryptographic algorithms and multiple key concepts has been discussed in paper [2]to highlight the categories of keys in cryptographic algorithms. Different cryptographic algorithms like play fair cipher in3D image medium has been discussed in paper [3] and paper [4] concentrated for colour medium. Symmetric and Asymmetric key exchange properties have been discussed in paper [5] and paper [6]. Paper [7] focuses on the application of watermarking in sensitive information like biometric data. Sensitive content can be authenticated through the application of watermarking. Application of steganography in recent days like IoT has been discussed in paper [8]. Security in IoT data transfer is also an important concern of late to protect data leakage in IoT data transfer channel. The concept of visual cryptography has been emphasized in paper [9] to focus the utility of visual cryptography in recent days. Paper [10] gives idea on different watermarking techniques and its application.

3 Data Security Techniques

Information sharing depends upon transferring data in multiple form like text, image, audio, video etc. Securing of data can be achieved in two ways i.e. Data hiding and Cryptography. Data hiding deals with concealing of sensitive information into various

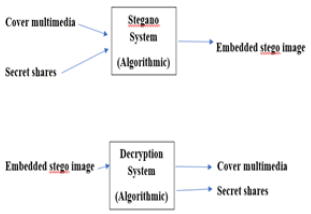

Fig. 1. Encryption and Decryption system

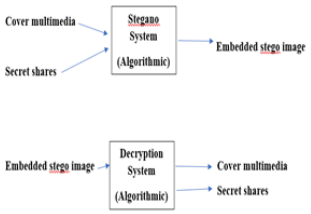

Fig. 2. Steganography system

cover medium. Cryptography deals with converting a readable text into unreadable text.

3.1 Cryptography

Cryptography is used to convert a readable plain text into unreadable cipher text by applying cryptographic encryption algorithm and keys. Cipher text is used and transferred among users so that it will not be recognised by unauthorised users [6]. Cryptographic decryption algorithm is used to make the cipher text into readable plain text at the end point to the authentic users so that data can be readable by using keys stated in Fig 1. Key is generated with the combination of numbers or alphabets or bit string. Depending upon the use of key cryptography can be differentiated into two categories. Asymmetric key cryptography uses two different key i.e. both public key and private key [5]. Symmetric key cryptography uses same key for both encryption and decryption [4]. Original confidential information can be hidden under any cover medium like image, audio, video etc. and can be transferred securely to the authentic user. Authenticity of the sender can also be verified using watermarking.

3.2 Steganography

Steganography states that the sensitive information will be embedded into cover medium and the cover medium will be sent to the receiver [8]. The data will be extracted from the cover medium in the receiver end. Thus ensures the security that embedded information will not be disclosed to anyone except appropriate receiver stated in Fig. 2. Based on the cover medium Stenography can be subdivided into some segments [8]. Text Steganography: Text file has been used as cover medium to embed the secret data into it. Image Steganography: Image file has been used as cover medium to embed the secret data into it. Audio Steganography: Audio file has been used as cover medium to embed the secret data into it. Video Steganography: Video file has been used as cover medium to embed the secret data into it.

3.3 Watermarking

Watermarking concept is introduced to provide authenticity on data to protect from alteration and tampering. Secret logos are used visibly or invisibly to protect data and provide copyright of the authorised users. Logos are used to authenticate the appropriate user. Based on the visibility of the logo watermarking can be categorised into two segments [7]. Visible Watermarking: Watermarked logo is visible to the user after embedding it onto data medium [10]. Invisible Watermarking: Watermarked logo is not visible to the user after embedding it onto data medium [10]. The efficiency of watermarking is measured by factors like Robustness, Imperceptibility, Transparency and Data payload [7].

3.4 Visual Cryptography

Visual cryptography is introduced in recent days after gradual development of conventional cryptographic concepts. In visual cryptography visual data like image, audio, video has been encrypted using respective algorithms. Multimedia data is segmented into different parts to generate shares. These share are transferred to receivers thorough different medium. Decode of the actual data from these shares takes place in receiver end [9].

4 Recent applications of Data Security

Data security principles has huge impact on digital medium where mostly sensitive data is used in recent day scenario. Medical image authentication, Digital document authentication could be done properly through data security approaches. Data security also plays a vital role in sensitive data transfer in defence organization, economic transfer, data protection.

5 Conclusion

This paper mainly focuses on the utility of data security in recent digital data communication. Different data security aspects have been discussed in this paper to focus the prime features of data security in electronic medium to protect the sensitive and confidential data from unauthorised access.

6 Future Scope

Data security can be implement in different sensitive aspects like protection of epic information, protection of adhar information using biometric identification, evaluation sheet protection etc.

Declaration: The authors declare no conflicts of interest.

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A COMPREHENSIVE ANALYSIS ON SUNSPOTS: AN ODYSSEY WITH THE ASTRONOMY CLUB

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ABSTRACT

The article presents a comprehensive overview record on sunspot observations conducted over a span of over four months. The study aimed to characterise and monitor sunspot activity on the Sun's surface. High-resolution images and data were acquired using Dr. Maddy's 150mm EQ Refractor Telescope, enabling the precise measurement of sunspot positions, sizes and magnetic field properties. Complementary validations were analysed as well. The observations reveal a dynamic and evolving sunspot population with periodic variations and long-term trends. The findings contribute to our understanding of solar activity and its potential implications for space weather. This work underscores the importance of continued sunspot monitoring for space research and solar science. With this comprehensive analysis, we have presented an article which would be directly accessible and exploitable for future research.

Keywords: Sunspot, Heliophysics, Coronal Mass Ejections, Solar monitoring

1 INTRODUCTION

The Aztecs thought that their Sun god had pockmarks on his face. The ancient Chinese referred to them as stars inside the solar orb.One Renaissance astronomer argued that they were actually undiscovered planets. Today, some believe that their appearance is linked to waves of UFO sightings and paranormal activity. Others offer them as an alternative explanation for anthropogenic change. The rest of us wonder if they are the reason for dropped cell phone calls or static-plagued radio stations. Yes, we are talking about 'Sunspots', the peculiar dark areas that pop up frequently on the surface of the sun. The earliest record of sunspots is found in the Chinese book named "I Ching", published in the ninth century. The text describes that a Dou and Mei were observed in the sun, which refers to small obscurations. Sunspots were first observed telescopically in December 1610 by English astronomer Thomas Harriot. His observations were recorded in his notebooks and were followed in March 1611 by observations and reports by Frisian astronomers Johannes and David Fabricius. So what are Sunspots? They are areas of strong magnetic field concentrations (with field strengths of a few kG), which look darker than their surroundings on the solar surface. Sunspots usually ranges 5 to 50 millimetres and lifetimes from a fraction of a day up to three months. They are typically confined to the activity belt of an equatorial belt, which is between the equator and ±35 degrees latitude (Solanki, 2003).

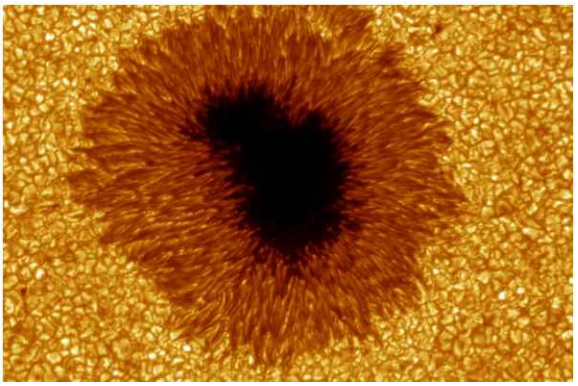

Fig. 1. Image of a Sunspot associated with AR 397 and observed with the Swedish Solar Telescope, at wavelength 630.2 nm (Fe I) on 3rd July 2003

According to the Royal Museums Greenwich, as the sun rotates at different speeds with the equator rotating faster than the poles, a "differential rotation" is created.

The interior and exterior of the sun rotate separately; the outside

Fig. 2. Image Captured by GCECT Astronomical Club on 27/09/2023 clearly depicts the clustered sunspots

rotates more quickly at the equator than at the solar north and south poles. Over time, that uneven movement twists and distorts the sun's main magnetic field. This disturbance in the sun's magnetic field forms pores that can grow and join together to form larger pores or proto-spots that eventually become sunspots. A group of sunspots is thus collectively known as an active region. The dark interior of a sunspot, called the umbra, is about 1,600 degrees cooler than the rest of the sun's surface. It is surrounded by a larger, lighter area called the penumbra, which is about 500 degrees cooler than the rest of the sun. Their darkness is due to a strongly reduced radiative flux caused by the suppression of convection by the magnetic field. This results in the dark appearance of sunspots.

According to the National Weather Service (NWS), the magnetic field in active sunspot regions can be some 2,500 times stronger than that of the Earth's. The strong magnetic field inhibits the influx of hot, new gas from the sun's interior, causing sunspots to be cooler and appear darker than their surroundings.

Now, there arises a random question in our mind that is why do sunspots occur in groups? Loops, which are like the magnetic field from a horseshoe magnet embedded in the Sun's visible surface, push through this photosphere. The magnetic loops have north polarity and a south polarity where they enter and exit the Sun called "feet". If the magnetic field at the base of the loop is strong enough, it prevents the conveyor belt-like transport of energy from the Sun's interior to the surface because charges cannot cross magnetic field lines.

Sunspots usually appear in pairs or in groups on either side of the sun's equator, between 40 degrees and 50 degrees latitude north and south. The turbulent motions in the Sun's interior fragment the loops in the solar magnetic field. Sunspots generally appear in opposite-polarity pairs or groups when the magnetic field is fractured. If one foot of the magnetic loop becomes too spread out, it may be too weak to form a sunspot, and the opposite-polarity sunspot will appear as an individual but the ghost of its partner's magnetic field still remains. And sometimes the magnetic field can emerge to the surface fractured and tangled, leading to a great and confusing sunspot group. Further, a directory of outcomes were observed. The magnetic field lines near sunspots often tangle, crucifix and reorganise. This can cause a sudden explosion of energy called solar flare.The solar flare explosion's energy can be equivalent to a trillion 'Little boy' atomic bombs dropped on Hiroshima and Nagasaki in 1945. Solar flares release a lot of radiation into space. When powerful enough, it can even disrupt satellite and radio transmission on the Earth. Its severeness can also cause 'geomagnetic storms' that can damage transformers in power grids. Solar flares are sometimes accompanied by a Coronal Mass Ejection (CME). CMEs are huge bubbles of radiation and particles from the Sun's corona (outermost region of the Sun's atmosphere). They explode into space at very high speed when the Sun's magnetic field lines suddenly reorganise. Sunspots can cause geomagnetic storms in Earth's magnetosphere. During a solar maximum, when sunspot numbers are at their peak, the Sun emits more radiation than usual (referred to as CME). Plasma emitted from the Sun shoots millions of electrons and protons towards Earth. These charged solar particles can enter the atmosphere and create mesmerising auroras, but they can also disrupt infrastructures such as satellites, navigation, communication and the power grids.

2 OUR JOURNEY AND OBSERVATION

2.1 JOURNEY

The Astronomy Club embarked on its journey with a shared passion for the cosmos. It was the time when we were in the freshman year of our college (Batch : 2021-25) and suddenly we witnessed the telescope at our Physics laboratory. Our curiosity to know about it dragged us to our Prof. Dr. Nilesh Mazumder , our Physics professor, who briefed us about it. It was bought and operated under the supervision of Prof. Dr. Saibal Roy during the COVID pandemic which was halted for almost a year after that. This curated a sense of engrossment among us and thus in its infancy, we emanated a plan to organise the first ever Summer Sky Watching Camp completely under the supervision of Dr. Nilesh Mazumder, Dr. Prasenjit Paul Dr. Saibal Roy in the year 2022. Since it was the first time so we captured a few images of the moon and even witnessed a few sunspots with the telescope without the use of any filter and were more or less successful in the objective. This marked the infant stage of our Astronomy Club.

As the club gained momentum, it organised the Winter Sky Watching Camp where we captured Jupiter using the barlow lens along with the moon. This was a great achievement for us as despite the climatic and other chaotic challenges, we came up even better defeating all those. With this we realised that we can captivate not just the sun, moon or jupiter but even other celestial objects. Astronomy themed talks and meetings became regular occurrences, fostering a sense of wonder and connection with the celestial world. It was marked by a continuous pursuit of both theoretical and practical understanding , creating a dynamic and engaging environment for all involved.

To pursue our zeal and follow it with the microscopic phe-

nomenons of the celestial objects and upgrade ourselves to a level higher, Prof. Dr. Nilesh Mazumder was approached by us. We shared our opinions to expertise the setup even better in usage. He guided us and so we reached out to our honourable principal Prof. Dr. Krishnendu Chakraborty. We presented our views to him with appropriate analysis and thus requested him for the purchase of essential assistive instruments of the telescope such as several filters like that of the moon filter, solar filter, planetary filters, CMOS, etc. Thus emerged the need of a team to chalk out the plans and function properly. This led to the formation of the GCECT Astronomy Club. Its members are the interested collegiates from all the years of the college.

The GCECT Astronomy Club after getting its recognition started working full-fledgedly. As it started maturing, it sought to leave a lasting impact. Its initiatives expanded with the club hosting regular Sky Watching Camps, Astrophotography, Astronomy Quizzes and several other activities contributing to scientific educational programs and providing valuable insights. Our journey had many ups and downs. One of the major challenges was the setback of the telescope. Many instrumental parts were rusted which was revived by our approach to the service centre of Dr. Maddy's telescope. The journey, though challenging at times, was characterised by a collective dedication to spreading the joy of astronomy and fostering a sense of scientific curiosity.

In retrospect, the Astronomy Club's journey was not merely about witnessing the celestial bodies; it was about fostering a community of enthusiasts. From its humble beginnings to becoming a beacon of astronomical passion, the club's trajectory mirrored the vastness of the cosmos it sought to explore and share. The sense of camaraderie and shared enthusiasm propelled the club to new heights, transforming it from a small interest group to a recognized entity within the college entity. The Astronomy Club of GCECT thus abides by its motto that is - where the universe is our playground and the celestial objects are our guiding lights.

2.2 INSTRUMENTAL ANALYSIS

Our journey as an Astronomical Club had the privilege to use Dr. Maddy's 150mm EQ Refractor Telescope. It impressively boasts a 150mm aperture and a focal length that extends up to 1200mm, allowing a persuasive magnification of up to 554 times. It is equipped with an EQ-4 equatorial mount featuring setting circles, which aids in precise sky object location and tracking. The telescope's sturdy tripod, constructed with steel legs, provides exceptional stability and eliminates vibrations. A key feature of this telescope is its optical design, which falls under the refractor category. The eyepiece's dimensions are 1.25 inches, and it comes

Fig. 3. Dr. Maddy's 150mm EQ Refractor Telescope

with PL eyepieces of 25mm and 6.5mm. Additionally, there is a 3X Barlow lens and a 10x30 finder scope with 1.5x erecting capability. One notable advantage of the refractor telescope is the absence of a central obstruction, which can positively impact image clarity and attributes. It is a remarkable instrument for exploring the wonders of not just the night sky but also that of the day.

Fig. 4. Converter lense, Solar filter, CMOS camera(8-24mm)

The Sun is the celestial object that can easily harm us. The same solar rays that cause sunburn will also burn the retinas of our eyes. So, in order to safely practise solar viewing, we need the right equipment. For our 6 inch telescope we purchased a solar filter fitting perfectly.

To zoom from low to high power in an instant, we use a multi-coated 8-24MM ZOOM EYEPIECE which is compatible with

Observation Month with year	Number of Sunspots
April 22’	5
July 23’	8
Aug 23’	11
September 23’	23
October 23’	5

Table 1. Sunspots observed over the years

any telescope that accepts 1.25” eyepieces having 40 to 60 degree field of view, with 15 to 18 millimetres eye relief.

We, being future engineers, implemented digital technology to capture minutest of the details. Equipped with the new high-sensitivity SONY IMX225 CMOS colour sensor, the BRESSER HD moon and planet camera delivers amazing image results with very short exposure times. The particularly low noise level ensures an exceptionally high brilliance and no cooling is required. Due to the high native pixel resolution of 1280x980, stunning images of the sun were taken. Windows was used to capture pictures and the ToupSky software was used which not only offers the necessary basic functions for image and video recording but also various obliging special functions for image post-processing and for setting up the guider. Functions such as live image display, exposure settings, white balance, dark image capture, stacking, timelapse recordings and much more can be individually configured.

3 OBSERVATIONS AND RESULTS

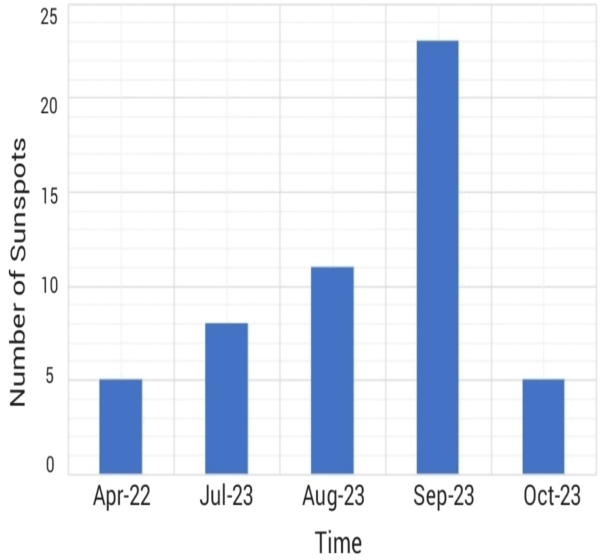

Fig. 5. Number of Sunspots VS Time graph

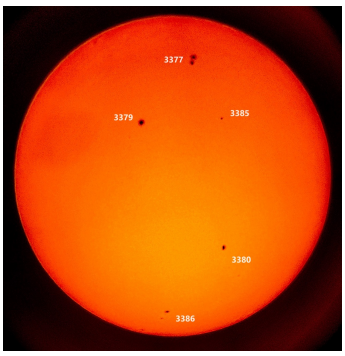

Fig. 6. Captured on July 27,2023 by GCECT Astronomy Club

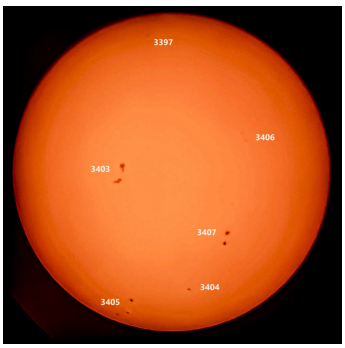

Fig. 7. Captured on August 16,2023 by GCECT Astronomy Club

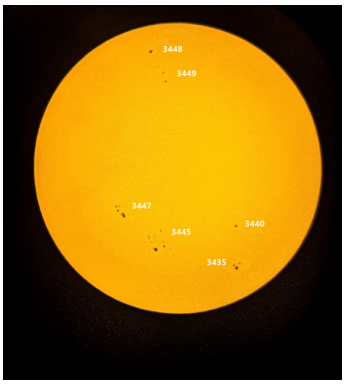

Fig. 8. Captured on September 27,2023 by GCECT Astronomy Club

Table 2. Observed on July 27, 2023

region	Configuration group	Magnetic type	Spot classification type	Penumbra type
3379	H	unipolar	alpha	Penumbra, symmetric<2.5 degree
3377	H	unipolar	alpha	Penumbra, symmetric<2.5 degree
3385	A	unipolar	alpha	No Penumbra
3380	H	unipolar	alpha	Penumbra, symmetric<2.5 degree
3386	C	bipolar	beta-delta	Penumbra with spot on one polarity only

Table 3. Observed on Aug 16, 2023

region	Configuration group	Magnetic type	Spot classification type	Penumbra type
3379	H	unipolar	alpha	Penumbra, symmetric<2.5 degree
3377	H	unipolar	alpha	Penumbra, symmetric<2.5 degree
3385	A	unipolar	alpha	No Penumbra
3380	H	unipolar	alpha	Penumbra, symmetric<2.5 degree
3386	C	bipolar	beta-delta	Penumbra with spot on one polarity only

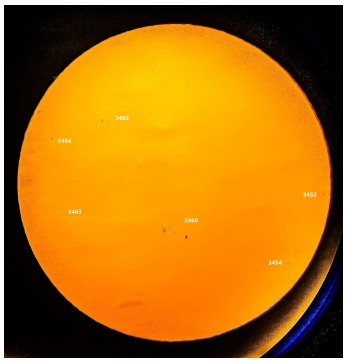

Fig. 9. Captured on October 11,2023 by GCECT Astronomy Club

3.1 April 9, 2022

Location: GCECT Hostel rooftop

Weather: Clear skies, no clouds

Time: 9:00 AM

This day marked an extraordinary attempt or beginning for our Astronomy club. We gathered at the hostel rooftop early in the morning and the enthusiasm was palpable. It was the first day of sunspot observation directly without the use of any filter. We only had our 6 inch EQ4 refractive telescope along with a 1.25" eyepiece sun filter. Our observation was accomplished from the college's hostel rooftop.The spots were not directly visible through our naked eyes at that phase of time. So, a paper as a screen was used so as to observe the filtered view of the low intensive sun body to witness the dark spots on its surface. Since it was the beginning phase of our observation, merely 1 to 2 spots were noticed. Solar filter vanquished due to the high intensity of the solar rays. This marked the end of the sunspot observation for the day.

3.2 July 27, 2023

Location: GCECT Hostel rooftop

Weather: Mid monsoon, passing clouds

Time: 7:00 AM

It was a glorious day with the first attempt to capture Sunspot pictures using a solar filter. The core members of the club assembled the setup. As of then, we had our solar filter with a celestron converter eyepiece (8mm-24mm). The first challenge for us was the weather, hence we had small windows for a very short period of time. Somehow we had managed to find a clear window and finally were successful in capturing some pictures of clear sunspots. But after the first attempt, some instrumental errors occurred in our EQ4 mount, so we just ended up capturing some partially satisfied images of sunspots but our target was not fulfilled yet.

3.3 August 16 , 2023

Location: GCECT Hostel rooftop

Weather: Sunny day

Time: 03:00 PM

The instruments were assembled. CMOS camera was used for the first time along with the software ToupSky for capturing the photographs. The telescope was then set up in the observation plane and aligned our cross-viewer with the middle of the Sun. It proceeded to take pictures of the Sun with the attached solar filter. During the session, we came across the over-magnification problem of the CMOS camera which restricted us to take a full length picture of the Sun. To overcome the problem, a 0.5X extender was placed before the eyepiece and attached CMOS to it, which significantly reduced the magnification and allowed us to capture and observe the sunspots effectively. A series of photographs featuring the sunspots was captured using the mentioned software.

Table 4. Observed on Sept 27, 2023

region	Configuration group	Magnetic type	Spot classification type	Penumbra type
3448	H	unipolar	alpha	Penumbra, symmetric<2.5 degree
3449	B	Bipolar	Beta	No Penumbra
3447	C	Bipolar	Beta-delta	Penumbra with spot on one polarity only
3445	C	Bipolar	Beta-delta	Penumbra with spot on one polarity only
3435	D	bipolar	Beta	Penumbra on spots of both polarities
3440	A	Unipolar	Alpha	No Penumbra

Table 5. Observed on Oct 11, 2023

region	Configuration group	Magnetic type	Spot classification type	Penumbra type
3462	D	Bipolar	Beta	Penumbra on spots of both polarities
3464	D	Bipolar	Beta	Penumbra on spots of both polarities
3463	C	Bipolar	Beta-delta	Penumbra with spot on one polarity only
3460	E	Bipolar	Beta	Penumbra with spot on one polarity only
3454	H	Unipolar	Alpha	Penumbra, symmetric<2.5 degree
3452	D	Bipolar	Beta	Penumbra on spots of both polarities

3.4 September 27, 2023

Location: GCECT Hostel rooftop

Weather: Clear skies, no clouds

Time: 9:00 AM

An attempt to capture a cluster of sunspots was targeted but whether we were lucky enough or not was the question of the day. This time with double the hope, energy and enthusiasm, we were again ready to capture at least some clusters of sunspots. In that unencumbered situation, we had finally got some clear clusters of sunspots. For us it was a great achievement as a crawling club. By this time we were well adapted and habituated to the instrumental faults. In fact, we learnt how to repair an EQ 4 mount to some extent ourselves. That day we succeeded our target and our expectations rose one level up.

3.5 October 11, 2023

Location: GCECT Hostel Rooftop

Weather: Radiant and sunlit

Time: 01:00 PM

It was a higher attempt of our solar observation , till date we had some satisfying data collection but we were heading for some more data. Sun was overhead and it was challenging for us to set the telescope as well as taking clear pictures. As you already know we were facing problems with our EQ4 mount. But it didn't stop us from collecting data and we finally ended up with some sunspot images. It was our last observation for the report and all the dedication and hard work of the team members finally have reflected in the results. We were slowly heading towards our next goal of writing this article and sharing our journey and data analysis with our beloved readers.

4 RECORDED DATA AND ANALYSIS

Sunspots vary in shapes and sizes. Few clusters of sunspots have a more complex magnetic structure than others and are more likely to produce solar flares. Despite such a diversity of shape and sizes astronomers have been able to define broad categories of sunspot groups. The first component of the classification scheme is the sunspot configuration group. There are 7 classes with each class representing an evolutionary stage that a sunspot group may go through during the course of its development and decay.A uni polar group is a single spot or compact cluster of spots with the greatest separation of spots less than 3 degrees. A bipolar group has two or more spots forming a group with a length (along its major axis) of 3 degrees or greater. More than half of the observed sunspot groups receive an Alpha or Beta classification, where bigger sunspots are often more complex and get a Beta, Beta-Gamma or Beta-Gamma-Delta classification. The records of sunspots observed through out the year are shown below:

5 CONCLUSION

The article, thus, provides an overview of the sunspot observation on the basis of the pictures taken by Dr. Maddy's 150mm EQ Refractor Telescope. The present review is, therefore, rather a list of existing records than a review of the physical understanding achieved from them. The members encourage efforts of digitising astronomical manuscripts to make them available and preserve them from potential loss.

All in all, our introspection has provided valuable insights into the dynamic nature and behaviour of sunspots. The thorough analysis presents a better understanding of the sunspot activity and its impact on solar phenomena. This research underscores the importance of ongoing observation in the field of astronomy. The findings presented in this article contribute to the growing

body of knowledge in solar science and highlight the dedication of our club members to the exploration of the cosmos. We hope that this research inspires further studies and encourages others to engage in the fascinating world of solar observation. The knowledge gained from this study can have significant implications for space exploration, satellite operations, and climate research. Also, continued observations and research into sunspots will be essential for refining our models and predictions related to solar activity. This will even help to mitigate the potential impacts of solar events.

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TO STUDY THE DIFFERENCE OF TEMPERATURE (DELTA) BETWEEN THE PEAK TEMPERATURE ON LEFT SIDE AND RIGHT SIDE DURING NORMAL FIRING IN GLASS TANK MELTING FURNACE

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ABSTRACT

Glass Tank Melting furnaces utilize a cross-fired approach, with burners alternating between the left and right sides in 20-minute cycles. During normal firing, a significant temperature difference, known as delta, is observed between the peak temperatures achieved on the left and right sides. This temperature delta exceeds the permissible limit of ±2 °C, resulting in furnace process instability and energy losses. To address this issue, a two-month action plan was implemented. In the first month, various parameters were analyzed to identify the key factors affecting the temperature delta. In the second month, corrective actions were taken, following a standard Kaizen procedure. Parameters investigated included combustion air flow, air-gas ratio, batch moisture, regenerator top and bottom temperature differences, natural gas flow, combustion air flow, draft pressure, burner parameters, flue gas analysis, net calorific value variation, and more. Notably, the combustion air flow, total gas flow, and air-gas fuel ratio demonstrated a strong correlation with the temperature delta. Several issues were identified, such as excess air and equipment calibration discrepancies. Recommendations for resolving these issues included adjusting excess air ratios, calibrating burner parameters, sealing cracks and holes, and upgrading flow measurement devices. Additionally, the study suggested reevaluating the correlation between net calorific value and gas flow. This investigation seeks to enhance furnace efficiency, minimize energy losses, and ensure a consistent temperature profile during glass production.

Keywords: Glass Tank Melting furnace, Temperature Delta, Combustion Air Flow, Net Calorific Value, Furnace Energy.

NOMENCLATURE

°C	Degree Celsius (Temperature)
MW	Mega Watt (Furnace Energy)
Kwh/Nm^3	Net Calorific Value
Kcal/Nm^3	Net Calorific Value
Kcal/Sm^3	Net Calorific Value
Nm^3/hr	Normal cubic meter flow of air or gas
Sm^3/hr	Standard cubic meter flow of air or gas

1 INTRODUCTION

Glass Tank Melting furnace is a cross fired furnace where firing occurs through burners from alternate sides in alternating cycles of 20 minutes. It has been observed that there is a temperature difference between the peak temperature attained during firing. That is the peak temperature attained during left side firing is not equal to the peak temperature attained during right side firing in the normal firing schedule of the GTF. This delta value exceeds the permissible limit value of ±2°C which is responsible for causing Furnace Process instability and Energy Losses.

To address the problem, a 2 month action plan was prepared. First month was dedicated to analyse various parameters and come to a conclusion to streamline our focus to a specific and the most appropriate parameters with the greatest influence to the problem and the Second month was reserved for Corrective Actions and Measures. A Standard Kaizen Procedure was followed.

All the possible parameters that were analysed are as follows. The following reasons might possibly influence and might be the possible reasons correlating to the given problem statement:

1)Combustion air flow in B3 port
2) Air gas ratio in port 3
3) Batch moisture
4) Regenerator top and bottom temperature difference
5) Total Natural Gas flow
6) Total Combustion Air flow
7) Total Air by Total NG ratio
8) Draft Pressure
9) Combustion Air Pressure by Burner HP Ratio
10) Effectof parasitic air

11)Burner HP,L.P., flame length
12) Flue Gas Analysis
13) Net Calorific Value Variation
14) Improper Air Flow and Gas Flow due to NCV variation
15) Air-Gas Fuel Ratio or Stoichiometric Ratio with NCV variation
16) Cross Check of the Chromatograph
17) Mega Watt Set Value vs. Temp of B3 Crown.

2 ANALYSIS OF THE PARAMETERS

2.1 COMBUSTION AIR FLOW IN B3 PORT

Air itself doesn't have any calorific value , so excess air flow might contain more parasitic air , so as the air flow increase but the gas flow is controlled thus incomplete combustion occurs as a result of which the furnace temperature as well as the delta value decrease . Thus we find a negative correlation .Its also observed that air flow follows a positive correlation , that is with increased air flow , furnace temperature increases and vice versa.

2.2 AIR GAS RATIO IN PORT 3

As fuel gas flow increases , Air to Gas ratio decreases . A stoichiometric ratio of air to gas of value 10:1 is to be maintained but that isn't occurring as was evident from real time observation and recorded values from the DCS .

2.3 BATCH MOISTURE

As batch moisture is higher it will absorb more heat for evaporation thus , temperature recorded will be lower and also the fuel consumed will be more thus causing energy instability and reduce sustainability .

2.4 REGENERATOR TOP AND BOTTOM TEMPERATURE DIFFERENCE

The idea is that , higher the temperature difference between regenerator top and bottom , higher is the heat amount absorbed by the combustion air . Now if a particular regenerator shows more difference in top and bottom temperature than the other regenerator , then the firing and thus the temperature attained on the other side is higher (side opposite to the regenerator in which the temperature difference came out to be higher) . It was observed that right regenerator top in port 3 attained higher temperature than the regenerator top in the left . So this should mean that when firing from the right side occurs , temperature attained should be more as the combustion air is flowing in through the Right Regenerator so it should mean the flue gases generated should heat up the left regenerator top more , but the exactly opposite of this is what occurs .

2.5 TOTAL NATURAL GAS FLOW

A positive correlation exists , as Natural Gas flow increase , more heat is generated during combustion thus a higher temperature is recorded. Natural gas flow depends on NCV value . The flow is adjusted accordingly by the DCS . The variation in the combustion air flow is the main contributing factor as its value is more for left side firing than right side firing . As combustion air flow is calculated on the basis of gas flow . Thus there is a direct correlation between NCV value , gas flow and B3 crown temperature delta

2.6 TOTAL COMBUSTION AIR FLOW

Its observed that combustion air flow is more for on the left side than on the right side by about 500 Nm^3/hr . Thus as the combustion air is more , homogenization is assumed to be more , more oxygen than the required stoichiometric ratio is available , thus combustion is more efficient . Now as the combustion air is more , which is not taking into account the amount of parasitic air , thus flue gas volume should be higher , thus draft pressure will be higher . Subsequent observations revealed just that .

2.7 TOTAL AIR BY TOTAL NG RATIO

A negative correlation is seen for air gas ratio and the B3 crown temperature measured , as the fuel gas flow increase , air by gas flow ratio decrease , more heat is generated , thus a higher temperature is recorded . As the combustion air flow is already higher by about 500 Nm^3/hr on the left side , so the increase in gas flow ensures complete combustion thus the temperature reached is also higher

2.8 DRAFT PRESSURE

A negative correlation is found between B3 crown temperature delta and draft pressure . Draft pressure is higher during the firing in the LHS than compared to the Firing that's occurring in the RHS. This can be attributed to the higher volume of flue gas which is being generated due to higher volume of combustion air flow in the LHS to the tune of 500 Nm^3/hr .

2.9 COMBUSTION AIR PRESSURE BY BURNER HP RATIO

B3 crown delta value was found to be low for a combustion air pressure to burner HP ratio value of 0.654 for LHS .B3 crown delta value was found to be low for a combustion air pressure to burner HP ratio value of 0.642 for RHS.This shows that calibration is required to maintain similar Burner HP levels .

2.10 EFFECT OF PARASITIC AIR

Excess air that enters the furnace through coolant lines or through cracks and pores is known as parasitic air . Various sources of

parasitic air in the furnace are :- 1)Cooling Air 2)Air Leaks Air Leaks can occur through cracks and holes . Cracks can occur due to wear and tear , weathering , corrosion and through thermal spalling . During regenerator raft condition checking , several cracks were observed in the regenerator bottom raft window section in both the regenerators of the furnace .All the cracks were then sealed to prevent Air Leaks through these .

2.11 BURNER HP , LP , FLAME LENGTH

Flame length depends on the HP , LP values . Also the inclination of the flame , whether it is parallel to the batch or at an angle to it , also is an important factor . Visually , flame during left firing is more parallel to the batch-line compared to the flame during right side firing .Since , the HP , LP values for the natural gas through the burners is comparatively more in the LHS burners than the RHS (only exception being the B3 port burners) , the flame length should be more , so should be the intensity . But due to human error , the flame length is assumed to be same . There is no arrangement to validate flame length , temperature , velocity in this furnace . But various input data (burner angle , HP , LP value of natural gas) implies , flame during the left side firing should be longer , and be of higher intensity.This assumptions should be validated and if a discrepancy is found then it should be corrected in order to obtain an uniform distribution of flame . This will also help to cut down cost and improve energy efficiency by reducing over firing and excess flow of natural gas .

2.12 FLUE GAS ANALYSIS

Flue Gas analysis was performed to study how the composition of the flue gas was used in calculating the amount of combustion air that is to be supplied . The volume of combustion air depends on the oxygen and CO composition of the flue gas . No such variations were found in our study from flue gas , nonetheless it is an important parameter . Flue Gas analysis is done twice a month on weekends.

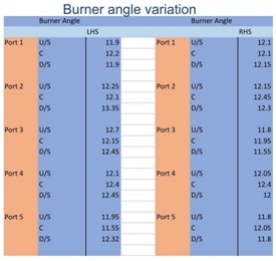

Fig. 1. This Chart represents a comparison between Burner Angle on both side of the GTF.

	HP	LP	Flame Length
HP	1		
LP	0.893237	1	
Flame Length	0.850914	0.86595	1

Fig. 2. This Chart represents a correlation between HP , LP and Flame Length.

It is observed that burner angle for port 2 and 3 is a bit more for LHS . Thus the inclination of the flame will be a bit more towards the crown for the LHS as compared to the flame angle on the RHS.

Fig. 3. This Chart represents a comparison between burner energy.

Thus the energy capacity for burners in B1 , B2 , B3 , B4 , B5 of LHS is higher compared to that of the RHS.

2.13 NET CALORIFIC VALUE VARIATION

The Gas used to support combustion is Natural Gas which is supplied by GAIL. There is an instrument which calculates the NCV of the gas continuously at every 3 minutes interval. The instrument is called the Chromatograph. Depending on the Value of NCV of the Gas at each instant, the Gas Flow and the Air Flow gets changed. Too much of change in NCV is the main factor for temperature fluctuation and also Furnace energy leakage. To study this variation , Manual Data of 24hrs was collected, which contained the component Analysis of the NG captured by the chromatograph.

Methane is the main component of the NG. Normally whenever there is a decrease in the Methane %, Ethane or other hydrocarbon isexpected to increase and the NCV value gets higher and vice versa also happens. Here the opposite is happening, i.e., with Methane % increase, the NCV is increasing and with a decrease in Methane % , NCV is decreasing. Probability: Some component with lower CV is increasing with decrease in Methane %.

2.14 IMPROPER AIR FLOW AND GAS FLOW DUE TO NCV VARIATION

Now since there is a variation in the NCV, the Gas Flow and Air Flow gets changed accordingly. The Theoretical model suggests that whenever NCV increases, the gas flow gets decreased and the Air Flow either remains constant or there is a very slight decrease in it. Similarly whenever NCV decreases, the gas flow gets increased and the Air Flow either remains constant or there is a very slight increase in it.

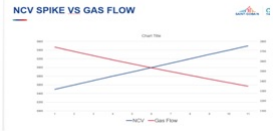

Fig. 4. This graph shows the Gas Flow whenever NCV increases.

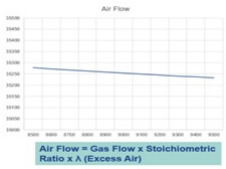

Fig. 5. This Graph shows the expected Air Flow with corresponding NCV increase.

Now we perform a check to see whether its performing properly.

2.15 AIR-GAS FUEL RATIO OR STOICHIOMETRIC RATIO WITH NCV VARIATION

With NCV Increase, Air Gas Fuel Ratio or Stoichiometric Ratio must increase and vice versa.

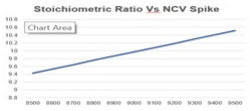

Fig. 6. Stoichiometric Ratio vs NCV spike.

2.16 CROSS CHECK OF THE CHROMATOGRAPH

The Chromatograph calculates the NCV and Composition of the Natural Gas. So, we perform few calculations by other methods to see whether the reported NCV of the gas by the Chromatograph is correct or not. We performed this by comparing the Unit Conversion Method (which occurs in the chromatograph) with other 2 methods. The other two methods are Wiley's Formula and the Formula given by Gujrat Gas Corporation Limited.

2.17 MEGA WATT SET VALUE VS TEMPERATURE OF B3 CROWN

Whenever there is any Change in the B3 Crown temperature, the MW Set Value is adjusted manually. For example, whenever temperature increases, MW Set Value is decreased by a Step Manner using a fixed value interval. Similarly if temperature decreases, MW Set Value is increased by a step manner using the same fixed value. We did a cross check to see whether the fixed value by which increase and decrease of the MW Set value is being done is correct or we need to do some changes in it.

3 EQUATIONS

3.1 CALCULATION OF EXCESS AIR

$$\text{Excess air} = \frac{\text{Measured } O_2\%}{20.9 - \text{Measured } O_2\%} \times 100$$

Overall $O_2\%$ in flue gas regenerator = 10- 12% . If measured $O_2\%$ is 1.8 then excess air = 9.4 % . If measured $O_2\%$ is 2 and above the excess air = 10 and above %.

3.2 PARASITIC AIR

$$\text{Parasitic Air} = \left[\frac{M_{\text{real } O_2} \times F_{0\%O_2 \text{ total fumes}}}{100 \times 0.21 \times \left(1 - \frac{M_{\text{real } O_2}}{100 \times 0.21}\right)}\right] - (F_{\text{CA}} - F_{\text{SA}}) \quad (1)$$

Here $F_{CA} = F_{\text{Combustion Air}}$

$F_{SA} = F_{\text{Stoichiometric Air}}$

3.3 STOICHIOMETRIC AIR

$$\text{Stoichiometric Air} = F_{\text{gas}} \times V_{\text{gas}} + F_{\text{oil}} \times V_{\text{oil}} \quad (2)$$

This function calculates the combustion air flow rate needed for the complete combustion of the injected fuel flow. The calculation depends on the fuel feature Va, the volume of air Nm^3/hr needed to burn 1 Nm^3/hr of gas or 1kg of oil and the fuel flow rate $D_gas/fuel$

3.4 MW

$$\text{MW} = \frac{\text{NCV (kCal/Nm}^3) \times \text{Gas Flow}}{860 \times 1000} \quad (3)$$

3.5 AIR-GAS FUEL RATIO OR STOICHIOMETRIC RATIO CALCULATION

$$\text{Stoichiometric Ratio} = 0.944051 \times \text{NCV} + 0.115472 \quad (4)$$

3.6 AIR FLOW CALCULATION

$$\text{Air Flow} = \text{Gas Flow} \times \text{Stoichiometric Ratio} \times \lambda \text{ (Excess Air)} \quad (5)$$

3.7 UNIT CONVERSION METHOD

$$\text{GCV MJ/m}^3 \times 239.006 = \text{GCV Kcal/Nm}^3 \quad (6)$$

$$\text{NCV MJ/m}^3 \times 239.006 = \text{NCV Kcal/Nm}^3 \quad (7)$$

3.8 WILEY'S FORMULA

Find out the GCV in KJ/mol of individual components. Find out the Molar Mass of the components as well,

Calculate GCV in kwh/NM3, using the formula

$$\left[\frac{\text{CCIC}}{100}\right] \times \frac{\text{GCV in KJ/mol}}{3600 \times \text{Volume Mol}} \quad (8)$$

Here CCIC = Chromatograph Composition of individual component

Find the total adding all the individual GCV in $kWhr/Nm^3$

Calculate GCV in kwh/NM3, using the formula

$$\text{GCV Kwh/Nm}^3 - \left[\frac{\left(\frac{\text{no. of H atom}}{2} \times \text{LO } H_2O\right)}{3600 \times \text{Volume Mol}}\right] \times \text{CC} \quad (9)$$

Here CC = Chromatograph Composition.

Also sum all the individual values The total GCV and NCV in $Kcal/Nm^3$ using the following formula:=

$$\text{GCV in Kwh/Nm}^3 \times 860.42065 \quad (10)$$

$$\text{NCV in Kwh/Nm}^3 \times 860.42065 \quad (11)$$

3.9 GUJRAT GAS CORPORATION LIMITED'S FORMULA

$$\text{Molar Mass} \times (\text{Composition } \%) \quad (12)$$

$$\text{Calculate g/mol} = \sum \text{of all individual Masses} \quad (13)$$

$$\text{Calculate g/l} = \frac{\sum \text{of all individual Masses}}{22.4} \quad (14)$$

$$\text{CCVIC} = \frac{\text{CV in MJ/Kg} \times \text{Mass}}{22.4\,(\text{g/l})} \quad (15)$$

Here CCVIC = Calculate Calorific Value by Vol. for individual components

$$\text{Sum of all in KJ/l} = \sum \text{of the NCV by vol of individual components} \quad (16)$$

$$\text{Calculate NCV in Kcal/Nm}^3 = \frac{\text{NCV in KJ/l} \times 4.18}{1000} \quad (17)$$

4 FIGURES.

4.1 B3 CROWN TEMPERATURE VARIATION BETWEEN TWO CONSECUTIVE LEFT SIDE FIRING

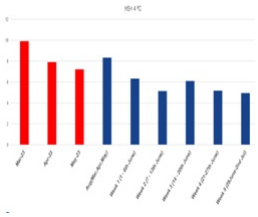

Fig. 7. B3 Crown Temp Variation between two consecutive left side firing.

4.2 THEORETICAL MODEL

This Model Suggests the behaviour of the Gas Flow , Air Flow and Air-Gas Fuel Ratio along with NCV variation.

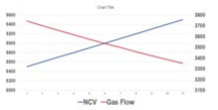

Fig. 8. NCV Spike vs Gas Flow.

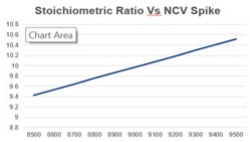

Fig. 9. Stoichiometric Ratio vs NCV Spike.

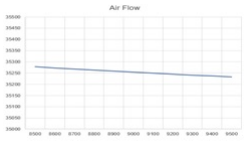

Fig. 10. Air Flow Variation.

4.3 MW SET VALUE

Fig. 11. MW Set Value 1

Fig. 12. MW Set Value 2.

5 TABLES.

5.1 THEORETICAL MODEL

NCV (Kcal/Nm3)	MW	Gas Flow Nm3/hr
8500	37	3743.529
8600	37	3700
8700	37	3657.471
8800	37	3615.909
8900	37	3575.281
9000	37	3535.556
9100	37	3496.703
9200	37	3458.696
9300	37	3421.505
9400	37	3385.106
9500	37	3349.474

Fig. 13. NCV Variation affecting gas flow

NCV	NCV KWH	V_a	Excess Air	Gas Flow	Air Flow	Air Gas Fuel Ratio
8500	9.86	9.423815	1	3743.529	35278.33	9.42381486
8600	9.976	9.533325	1	3700	35273.3	9.533324776
8700	10.092	9.642835	1	3657.471	35268.39	9.642834692
8800	10.208	9.752345	1	3615.909	35263.59	9.752344608
8900	10.324	9.861855	1	3575.281	35258.9	9.861854524
9000	10.44	9.971364	1	3535.556	35254.31	9.97136444
9100	10.556	10.08087	1	3496.703	35249.83	10.08087436
9200	10.672	10.19038	1	3458.696	35245.44	10.19038427
9300	10.788	10.29989	1	3421.505	35241.14	10.29989419
9400	10.904	10.4094	1	3385.106	35236.94	10.4094041
9500	11.02	10.51891	1	3349.474	35232.83	10.51891402

Fig. 14. NCV Spike effecting air flow and stoichiometric ratio

5.2 DATA COLLECTION FOR NCV CROSS CHECK

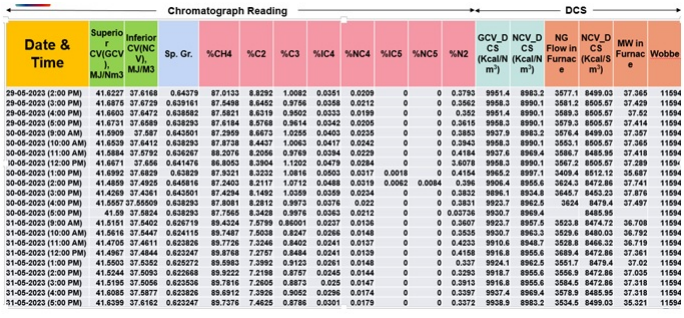

Fig. 15. Data Collection

6 CONCLUSIONS.

The following observations and suggestions can be made :

6.1 PRACTICAL SET OF CONCLUSIONS BASED ON PHYSICAL INSPECTION

1) Combustion air flow is more during left side firing, reason can be attributed to the fact that the excess air ratio setting is a bit more ports on left side which is set based on flue gas analysis of oxygen amount .
2) B3 crown delta value is observed to be low when furnace pressure is around 5.17 Pa .
3) B4 burner HP LP values for NG flow is comparatively more in the left side compared to that in the right side , calibration required .
4) B3 burner HP LP values for NG flow was observed to be comparatively less in the right side compared to the left side , calibration was done to make them equal .
5) Maximum temperature for B3 right regenerator top (Target wall) was found to be higher during left firing compared to left regenerator top (Target wall) during right firing and minimum temperature for B3 right regenerator top (Target wall) was lower during left firing compared to left regenerator top (Target wall) during right firing . Possible reasons as observed are choking in the right regenerator top in B3 port.
6) Cracks and openings were found in the regenerator bottom peep window area . Sealing and repair work was done .
7) Cracks and holes were observed in the B4 skew-line area in the left side and holes in penetration wall area was found . Repair work and sealing was done in the observed area .
8) Burner coupling for manometer attachment , used for measuring burner HP LP values was found to be faulty , needs to be replaced.
9) Burner service life is almost at its last stage , as such calibration for HP LP of NG flow becomes difficult. It needs to be replaced.
It has been observed that the rate of rise of temperature during left firing is more steep compared to the rate of rise of temperature during right firing . Since the temperature of left regenerator is lower by 40 to 60 degree Celsius compared to the temperature of right regenerator , the temperature of combustion air is also low during left firing compared to right firing . But as the combustion air volume is more during left firing the combustion process is robust and the temperature rise of the combustion end product (flue gas) is higher. Also the temperature point from which left firing temperature rise start is lower compared to the temperature point from which right firing temperature rise starts . Due to difference in combustion air volume and difference in volume in oxygen required for combustion , the nature and total energy released during the firing process is different . Due to higher combustion air volume during left firing , mixed nature of reaction of heavier hydrocarbon occurs ,that is the oxidation of N-butane , iso-pentane etc. occur which produce soot (amorphous carbon) , which is susceptive to further oxidation , which on oxidizing produce CO and CO2 . Due to comparatively lower amount of combustion air in right firing , this reaction occurs to a lesser extent , thus the amount of CO formed is lower as confirmed by flue gas analysis.

Fig. 16. DCS view of the problem statement

6.2 ANALYSIS OF VARIOUS DATA

1)Net Calorific Value Variation:

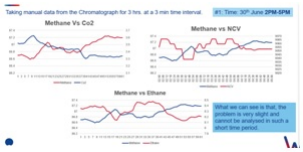

Fig. 17. Relation between different components of the NG 1.

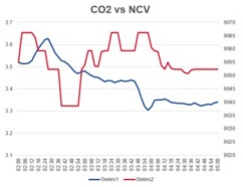

Fig. 18. CO2 vs NCV

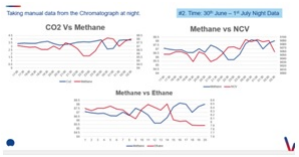

Fig. 19. Relation between different components of the NG 2.

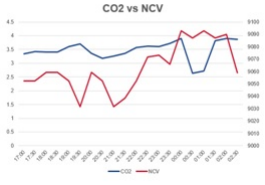

Fig. 20. CO2 vs NCV

2) From the Data Manually collected from the Chromatograph, we can say that, there is a possibility that the Directly Proportional behaviour of NCV with Methane can be due to the variationof CO2 % with Methane %.
3) Whenever there is an NCV spike CO2 % is taking Methane % thus decreasing the NCV.
4) This should not take place
Solution : We contacted GAIL authorities and discussed the issue and told to fix it.

6.3 AIR FLOW , GAS FLOW AND STOICHIOMETRIC RELATION CHECK WITH RESPECT TO THE THEORETICAL MODEL

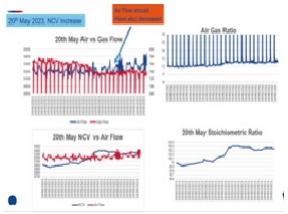

Fig. 21. NCV and other parameter variation on particular dates 1.

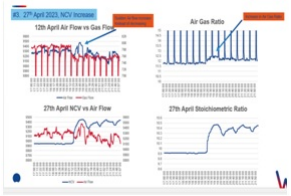

Fig. 22. NCV and other parameter variation on particular dates 2.

After Collecting Data , we can see that, with NCV increase or decrease , Gas Flow is following the theoretical model ,but Air Flow is not following the order due to which the Air Gas Fuel Ratio or Stoichiometric Ratio is also getting a bit hampered.
Factors which might affect the Air Flow:
1) Flow Meter : Anuubar Flow Meter
2) Excess Air
Now, Excess Air is kept constant, on reviewing much we could see that the problem mainly lies within the Flow Meter which measures the Air Flow. The flow meter used is Annubar Flow Meter. The Annubar primary flow element is a device used to measure the flow of a liquid, gas or steam fluid that flows through a pipe. It enables flow measurement by creating a differential pressure (DP) that is proportional to the square of the velocity of the fluid in the pipe, in accordance with Bernoulli's theorem.

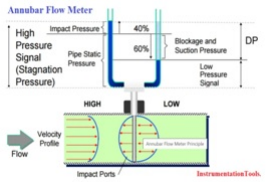

Fig. 23. Annubar Flow Meter

Thus the disadvantages of this flow meter are :
1) Single point measurement.
2) Pitot tube is fragile.
3) DP signal is low.
Suggestion: Installing a better Flow Meter with more accuracy and low cost.

Fig. 24. Comparison of other better flow meters.

6.4 CHROMATOGRAPH CROSS CHECK RESULT

Wiley's Formula :

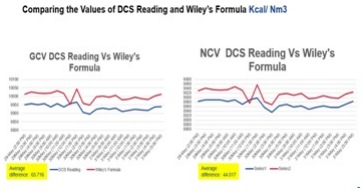

Fig. 25. Comparison of Wiley's formula with DCS reading.

GGCL Methodology :

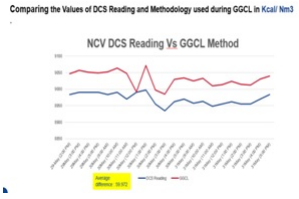

Fig. 26. NCV DCS reading vs GGCL methodology.

What we can see from both the cases that there are some differences, but that is negligible comparatively. So we focus on other issues neglecting this.

6.5 MW SET VALUE INCREASE OR DECREASE WITH RESPECT TO TEMPERATURE INCREASE OR DECREASE

Fig. 27. MW Set Value Variation 1.

Fig. 28. MW Set Value Variation 2.

Considering the Data collected Manually :
1) We can see that the change in MW Set Value is Altered corresponding to B3 Crown Temperature Variation.
2) The adjustment of MW Set Value is done with a value of ±0.2MWin maximum of the cases.
3) This is causing a very late action on the B3 Crown Temperature.
Suggestions:
1) We can try adjusting the MWSV with a value of 0.25-0.30 MW.
2) 6^{th} July – 7^{th} July : Adjusting MWSV with a value of 0.25 MW.

7 REFERENCES

1) Principle of Annubar Flow Meter, LinkedIn
2) Ultrasonic Flow Meter, India Mart

**The Data and all the other work has been inherited from Saint Gobain India Private Ltd, Jhagadia, Gujrat Plant l **