CHAPTER 6

DISCUSSION

In the previous Chapters, a number of firearm problems having forensic implications were considered and analytical data was generated by having recourse to modern methods of analysis. This includes development of computer software, high speed photographic analysis and external ballistics calculations. The stage is now set for a discussion of the results in the light of the past work done and the latest developments in the field. In the present Chapter, this has been attempted vis-a-vis the forensic problems as they exist in our country. Some suggestions for future developments have also been made.

COMPUTER SOFTWARE

In a case of shooting, the crime scene is one of the most fruitful sources of information. Important clues, if properly collected and evaluated, can give eloquent testimony at the trial. Some of the important pieces of firearm evidence are bullets, cartridges/cartridge cases and firearms. As a bullet is discharged through a rifled barrel, the rifling of the barrel gets engraved on its cylindrical surface. Measurements made on the bullet reveal the rifling specifications of the firearm through which it was fired. The rifling specifications of firearms vary considerably from manufacturer to manufacturer and this fact could be made the basis for identifying the type, make and model of a firearm. This has prompted the ballisticians to collect rifling specification data of firearms and arrange them systematically for practical use. Similarly, an indication of the manufacturer can be had from the headstamp code on the cartridge case and also from the similar codes embossed on firearms. As the number of manufacturers multiply and so also the variety of
firearms, the above mentioned data assumes voluminous proportion and ceases to be amenable to manual handling. The manual method which has been in vogue is, therefore, to be discarded because it is inconvenient, time consuming and impractical. The element of time has assumed great significance in the modern context when criminals operate in a sophisticated manner and use ultra-fast modes of transport. There is, therefore, a need for automated methods of identification. A computer is the natural choice because of its enormous capacity for data storage and adaptability for fast search and retrieval of data.

The BDP-100 computer used in the present work is a simple machine with sufficient memory to handle the volume of data likely to be encountered in forensic work. The programming has been done using BASIC language which is simple and easily understandable. This has resulted in a software which can be handled even by a technician with minimum training. The programme can also be run on any available PCs. The system is cheap and can prove to be ideal for a forensic set up.

**Rifling Specifications**

A reference to Chapter 1 reveals that the developed software on automation of firearms identification through rifling specifications is essentially based on :-

a) Arrangement of data on rifling specifications (groove width, number of lands grooves and direction of twist) for rifles, revolvers and pistols in a suitable form;

b) Ability for updating the stored data; and

c) Facility for search within specified limits.
The rifling specification data has been arranged in sequential files. The flow chart for creating such files (Chapter 1, Figure No.1.5) shows that the files can be created with ease. The computer programme for creation of files is given vide Hardcopy No.1.1. It is admitted that the search of a sequential file is time-consuming because each entry in the file is required to be checked sequentially. The system of random access file is faster but it was not feasible for the present case due to the possibility of overlap in the bullet groove width specifications. To cut down the time of search, a logical system of grouping data according to caliber, number of lands/grooves, direction of twist and type of firearm has been followed. The naming of files has also been done on the basis of these parameters thereby making their identity self-revealing. Thus, the file 22P18.6R will only contain the data of .22 pistols having six lands/grooves and a right direction of twist. Similarly, the file 32REV.6R will exclusively contain rifling specification data of .32 revolvers with six lands/grooves and right direction of twist. Since the parameters mentioned above can be ascertained easily from a visual examination of a fired bullet, only the relevant file need to be opened for conducting search. A substantial amount of rifling data can, therefore, be eliminated before initiating the search thereby saving considerable computer time. There may be border line cases where clear distinction between the type of firearm (e.g. between a revolver and a pistol bullet) may not exist. There may also be some cases of mismatching of ammunition. In such cases, it may become necessary to explore the other possibilities by searching the alternate files. It is thus evident that the stratification of data in distinct files as adopted in the present work has obvious advantage because it overcomes to a great extent the disadvantages of arranging the data in sequential files.

The rifling specification files have to be comprehensive in order that the results of search are fruitful in identifying the firearm. The files are required to be built up on the basis of data available in literature as well as that generated in various laboratories. The latter requirement is very
important because no laboratory can afford to have an exhaustive collection of data relating to firearms manufactured all over the world. It will, therefore, be a good practice for the laboratories to have a programme of exchanging data on rifling specifications. This brings to fore the problem of updating the data. The updating of sequential files on the RDP-100 computer is simple. The computer programme for updating files is given vide Hardcopy No. 1.2 in Chapter 1. To avoid duplication of data, it will be necessary to first check the availability of the new data in the existing files. If the computer responds to the new data (indicating its existence in the file), the same can be ignored, otherwise it can be entered and stored.

A search programme (Chapter 1, Figure No. 1.6, Hardcopy No. 1.4) is an important element of the overall scheme. The distinct feature of this programme is its ability to search the required data within certain limits which can be specified by a firearms expert. There can be measurement errors in the bullet groove width data which forms the basis of the search programme. To take into account these errors, it is necessary to search the measured bullet groove width between certain limits. A reference to practical illustrations given in Chapter 1 shows that the number of firearms which respond in a particular search is to some extent dependent on these limits. It is evident from Hardcopy Nos. 1.9 and 1.10 that the number of firearms which respond increase from 2 and 12 as the search limits are increased from (2) 0.002 inch to (2) 0.005 inch. A caution is, therefore, necessary in choosing the search limits. Too wide search limits which lead to numerous responses may not be of practical interest because it will be impractical for an investigating officer to search for so many weapons. At the same time, too narrow limits may miss the wanted firearm. A firearms expert has to be guided by his experience in setting the limits. His main aim should be to give proper guidance to the investigation in locating the correct weapon.

From the various computer search outputs given in Chapter 1, (Hardcopy Nos. 1.9 - 1.10) it is seen that apart from the details of the firearms, the output also provides
the source from which the data was originally obtained. This is helpful because a source can be rechecked, if necessary, for further information about the firearms. It is seen that the computerised system developed here takes into account the various eventualities that are likely to arise in a practical situation and can, therefore, be a positive assistance to the investigation.

Manufacturer's Codes on Firearms and Cartridges:

Another important piece of evidence is a cartridge/cartridge case. It can be recovered from the possession of an accused, from the chamber of a firearm or from the scene of crime. The semi-automatic-automatic firearms eject their empties with considerable force and these empties are generally found scattered near the place of shooting. Their collection by the criminal under the stress of crime conditions is generally not possible. As in the case of the bullets, the preliminary investigation can be guided by an examination of the markings on the cartridge/cartridge case. An important evaluation in this connection is the determination of the origin of ammunition. The determination of ammunition origin is specially significant in cases involving smuggling of ammunition or clandestine supplies by one country to another country. The origin of ammunition can be traced through the headstamp codes which assume various forms. Codes indicating the origin are also found to be present on firearms and they are, therefore, helpful in determining the origin of firearms. The present computerised system takes care of those codes present on firearms/cartridge cases which are in the form of English alphabets. There could be other types of codes in the form of emblems and designs but the same are not covered in the system developed due to the limitations of the BDP-100 computer.
The software developed has the following basic elements:

a) Arrangement of data and creation of sequential files;

b) Facility to update the data from time to time; and

c) Facility for fast search and retrieval.

The creation of sequential files in preference to random access files was again necessitated in this case also due to the possibility of overlapping of the codes. As in the case of rifling specifications, the slow response of the sequential file system has been overcome by a proper organisation of data. This consisted of grouping the codes starting with a particular alphabet in a single file so that it is not necessary to search the other files. The ammunition files have been distinguished from the firearm files to distinguish codes of the two categories. There were thus 26 files corresponding to the 26 alphabets for firearms and ammunition separately. A typical nomenclature for files containing codes starting with letter "A" is CODEC.A and CODEF.A. The letters "C" and "F" indicate the ammunition and firearm files respectively. Since this classification limited the number of entries in each file, the search was made rapid inspite of the fact that each entry is checked serially in a sequential file. The programme for creation of files (Chapter 1, Hardcopy No.1.11) as well as for search (Chapter 1, Figure No.1.7, Hardcopy No.1.14) are simple as in the case of rifling specifications. The in-built facility of updating the data is also available (Chapter 1, Hardcopy No.1.12).
Computerised ballistic data bank – A Projection for Future

At one time, the computerised ballistic data management was considered to be a tough job. But now, computer use has come of age and is no longer considered to be revolutionary or controversial. Though India entered the era of automation about two decades ago, forensic profession had to cut across many barriers. Till recently, the great deterrent to the introduction of computers in forensic ballistic data management has been the non-availability of suitable software. The development of software presented in this thesis is a step forward. The integration of computer and the forensic ballistic data management is expected to result in high efficiency. This integration will have its fullest flowering in the Computer Assisted Retrieval System (CARS). The CARS can literally be called cost effective solution to usual, manual data storage and retrieval system. It can be used as an interactive logical searching device. With the present developed software, the entire ballistic data can be captured on a few discs and the nucleus of a computerised ballistic data base can be created. Forensic ballisticians can, thus, relieve themselves of the usual problems of manually operated storage of data files.

The hardware and the packaged software are underscored by the following characteristics:

a) Low cost;

b) Suitable for specific ballistic data on rifling specifications and cartridge/firearm codes;

c) Minimum training time to operate;

d) Easy to operate;
e) Software is so tailored that it can take care of updating the stored ballistic data; and

f) Data can easily be transferred to a multi-user computer network system.

It is observed that about 90% of the firearms/ammunition manufacturer's codes are in English alphanumerical forms. But some countries have their codes in their own national language and some firms follow peculiar forms and figures for the purpose. The present software is unable to computerise such codes due to the limitations of the BDP-100 computer used in the study. Work is, however, in progress whereby it may be possible with the help of optical scanners to cover codes in forms/figures other than alphanumericals. The stored images of such forms/figures can then be matched with the unknowns, thereby making the software more comprehensive.

The nationwide informatics network, which can use satellite communication for connecting all the forensic science laboratories of the country with the National Centre at New Delhi, can make use of the present software for data storage, retrieval and dissemination. The National Centre can query the data bases in the individual forensic laboratories and vice versa. Thus, in the beginning, the Central and the State Forensic Science Laboratories can be the actual beneficiaries. But soon, India, which is one among the 40 member countries of the ITAR (International Trafficking in Arms) (64) can start using the software to trace the firearms/ammunition at an international level and thus can play a very active and significant role in controlling international trafficking in firearms/ammunition.
HIGH SPEED PHOTOGRAPHIC ANALYSIS

All ballistic phenomena such as muzzle blast, discharge of a bullet through a firearm and its travel through space, bullet impact on target, etc. are accomplished in such a short time that it is not possible for the human eye to follow the course of events that lead to the final result. In routine forensic work, one has, therefore, to be content with the final result. This is essentially a drawback because it beclouds the full understanding of the mechanism through which a particular ballistic effect is produced. A forensic scientist’s task does not end in the laboratory. He has to present his findings before the courts of law to substantiate his opinion. While photographs, charts, etc.; pertaining to bullet/cartridge case comparison serve a useful purpose in convincing the courts, the problems relating the impact, wounding and trajectory leave much to be desired in so far as the demonstrative aspect of the evidence is concerned. Often the courts are unable to appreciate the finer points relating to high speed events which are, generally, explained verbally and at the best demonstrated via their final effect rather than through the photographs depicting the systematic development of the events.

High Speed Motion Picture Photography (36-38, 44, 65-68) is known to the ballisticians as a technique which can reveal the course of high speed events by photographing the events at a rapid rate and then projecting the film at a much slower rate within the powers of comprehension of a normal human eye. While it found extensive use in defence ballistics (45-49), it has yet to become a part and parcel of the curriculum of routine work in a forensic set up. The cost of equipment and the psychological mental block in its operation have discouraged busy forensic ballisticians to lay their hands on this promising technique. Literature on the use of high speed photography in wound ballistics studies (39-43,69) is available. High speed
photographs of gas discharge (70-72) and muzzle blast (73) are also available but their forensic significance has not received due attention. The work reported in Chapter 2 and 3 clearly establishes that this technique can be exploited with advantage and ease in studying a variety of forensic problems including that of the countrymade firearms which is of great relevance in third world countries, especially India.

Before the technique is applied to analyse any ballistic phenomenon, it is necessary to make an in depth study of the event to be photographed with a view to settle the experimental parameters. In high speed photography, a sharp image on the film helps in making meaningful measurements. When the blur on the film is kept within limits, the image appears sharp. Combination of photographic parameters is actually responsible for the sharpness of image. When the high speed photographic experiments are conducted in a laboratory, space and lighting conditions are the main problems. Within limited laboratory room space, the gun is to be fixed, the field of view of the camera on the line of firing is to be adjusted and the artificial lighting is to be arranged. The camera settings are to be matched with the room space, lighting conditions and the approximate velocity of the projectile which is to be photographed. One has, therefore, to make repeated trials by running the camera at different frame rates to arrive at the correct combination of experimental parameters. This results in loss of film and wastage of time. The method of trial and error based on experience has been dispensed with in the present work by identifying the important experimental parameters and weaving a computer programme around them. This has resulted in a crisp and concise computerised system of analysis (Chapter 2) which can be used to analyse an event prior to high speed photography. This computerised analysis has been successfully used in jotting down the photographic parameters for studying ballistic phenomena in Chapter 3 (Table 3.4). An advantage of this programme has been that it, inter alia, suggests the amount of light required for photography.
thereby ensuring the success of a shot. The computer programme can be run even by a technician and therefore, once a firing experiment is set, the computer will give all details thereby making the high speed work simple and rapid. The integration of computer with high speed photography can, therefore, be considered as a step forward in simplifying and standardizing the practical application of this technique to forensic work.

A reference to Chapter 3 shows that the technique has been applied to study the ejecta of a variety of firearms, both factorymade and countrymade. The salient observations in respect of each firearm/cartridge combination have been given along with the high speed photographs. These observations coupled with the analytical data can form a basis for discussing the ballistic behaviour of countrymade firearms vis-à-vis their factorymade counterparts chambered for the common cartridge.

**Firearm Discharge Residue**

As a result of burning of propellant, gases are produced in the barrel of a gun which push the projectile out of the muzzle with high velocity. After the projectile leaves the muzzle, the gases still have considerable energy and rush out of the muzzle with great force constituting the muzzle blast. The muzzle blast carries with it unburnt/partially burnt grains of propellant and other firearm discharge residue contributed by the primer, propellant and the projectile. It will be ideal if there is no gas escape before the projectile leaves the muzzle. But this is never the case and there is always some escape of gas past the projectile. Whelen (74) observes: "Being heavy, the bullet starts forward slowly from the rising pressure of gas on its base. In the meantime, a small crevice has developed between the expanding case neck and the walls of the bullet. As the bullet has not yet advanced far enough to enter and seal the bore, this crevice between the neck and the walls of the bullet introduces a leak spot. The gas at high pressure leaks into every
crack and crevice that it finds. Some of it leaks into the crevice and around the bullet into the bore". In standard shotguns, the wadding materials are expected to effectively seal the leakage of expanding gases inside the barrel. But the high speed Photograph No. 3.16 (Chapter 3) shows that the gas comes much ahead of the shots. In the above photograph taken at a muzzle distance of 40 inches using a standard shotgun, it is seen that the powder gas front comes in the field of view and the shots follow after about 0.000666 second. There is no evidence of gas front in Photograph No.3.17 (Chapter 3) taken at a muzzle distance of 100 inches with the same firearm/cartridge combination. As a contrast, a reference to Photograph Nos.3.18-3.21 (Chapter 3) shows that in case of countrymade Shotgun Nos.1 & 2 using the same ammunition, there is no evidence of gas front at a muzzle distance of 40 inches. There is, however, evidence of a gas front moving ahead of shot column at a muzzle distance of 15 inches. The shot column appears in the field of view after a lapse of about 0.002 second (Photograph Nos.3.18 and 3.20).

While the velocity of gas front in case of factorymade Shotgun is estimated to be 520.5 ft/sec at a muzzle distance of 40 inches, its velocity in case of the countrymade Shotgun Nos.1 and 2 works out to be 910 ft/sec and 728 ft/sec respectively at a muzzle distance of 15 inches. The high velocity of gas front, its takeover by the shot column and its disappearance after a short travel clearly demonstrate the rapid retardation it undergoes in the atmosphere. The velocity of gas front is even found to be higher than that of the velocity of the shot column in case of countrymade Shotgun Nos.1 and 2 at a muzzle distance of 15 inches. In case of single shot projectiles (Chapter 3, Photograph Nos.3.10 - 3.15), there is no evidence of gas front because the muzzle distance at which these photographs were taken was too large to be within the reach of the gas blast.

It is well known that the rate of burning of propellant in a firearm is sensitively controlled by the surrounding pressure. Unless this pressure is maintained at a certain level, the burning will not progress. As soon as a
projectile is ejected from the muzzle, the pressure is released and consequently the burning of the propellant ceases. It is desirable that the design of the gun/ammunition should be such that the all burnt point of the propellant is well within the barrel. This ensures total consumption of the propellant and the availability of a substantial part of its energy for imparting kinetic energy to the bullet/shots. However, it is observed that in the best factorymade firearms, a small amount of unburnt/partially burnt propellant is invariably left. This is more so in case of short barrel weapons like pistols and revolvers. A faster burning powder is desirable in short barrel weapons but the rate of burning can not be increased beyond a certain limit otherwise it may lead to the development of abnormally high pressure which might cause a burst. Too slow a burning rate is also not conducive for the efficient consumption of propellant. A balance is required to be struck depending upon the type of propellant and the nature of weapon. When a factorymade cartridge is discharged through a countrymade weapon, it leads to mismatching of ammunition. Loose fitting, inadequate sealing, unwanted leaks, etc. result in inefficient burning of the propellant thereby causing a large amount of propellant remaining unburnt. This unburnt/partially burnt propellant is ejected through the muzzle along with the powder gases. It, however, loses its velocity rapidly due to the light weight and poor ballistic shape of the propellant grains. However, at close ranges of firing, the propellant grains have enough velocity to cause superficial penetration in the skin causing the well known phenomenon of "tattooing" which has forensic significance. A reference to Photograph No.3.12 in Chapter 3 clearly shows that unburnt/partially burnt sticks of cordite which is used as a propellant in the .303, ball, Mk7 cartridge are seen flying and their velocity is estimated to be 303.9 ft/sec at 24 inch muzzle distance. There is no evidence of such powder grains in any of the other photographs. Depending upon the size of the grain, its weight and velocity, the propellant grains are projected to varying distances.
The hot powder gases within the range of their action can produce terminal effects on the human body. One of such effects is burning/scorching. It is essentially a thermal effect which chars the human skin and singes hairs. Another close range phenomenon is blackening which is caused as a result of the dirty deposit made by the powder gases. Yet another important observation is that relating to the deposit of unburnt/partially burnt grains of propellant and other firearm discharge residue carried by the powder gases. All the above close range phenomena are often used to estimate the range of firing in forensic cases. It is obvious that all the close range phenomena are dependent on the dynamics of powder gases and the residue particles. Different firearm/cartridge combinations may behave differently which once again highlights the limitation of range estimates based on the generalizations given in text books. It also emphasizes the need of experimental tests with the crime weapon/ammunition to arrive at acceptable estimates of range in individual cases. Such estimates supported by high speed photographs can be very effective in convincing the courts regarding the validity of the opinion of a firearms expert. It can also help in making them understand the basis of such determinations.

**Bullet Stability**: –

Firearms such as pistols, rifles and revolvers which discharge single cylindro-conoidal projectiles invariably have a rifled barrel. The factorymade weapons of the above mentioned types viz., the .303 Enfield rifle and the .380 H & R revolver used in the present study had rifled barrels. The corresponding countrymade weapons viz., the Pistol Nos.1 and 2 and the Revolver Nos.1 and 2 had smooth bore barrels devoid of rifling. Further, the barrels of the countrymade guns were oversized as mentioned earlier. While the bullets discharged through the factorymade weapons were spin stabilized, the bullet discharged through the countrymade firearms did not have spin stabilization. Bullets such as those discharged through pistols,
revolvers and rifles, being cylindro-conoidal in shape, are base heavy and consequently their centres of gravity are behind the corresponding centres of pressure. The placement of centre of gravity behind the centre of pressure makes a projectile inherently unstable. This inherent unstable design of a cylindro-conoidal projectile necessitates the stabilizing action of spin to keep the projectile flying nose on. In the absence of adequate spin, they are bound to tumble. This is amply borne by the High Speed Photograph Nos. 3.11, 3.12, 3.14 and 3.15 in Chapter 3 where the .303 and .380 bullets discharged through countrymade firearms are seen tumbling. This is in contrast to the same bullets discharged through the factorymade weapons which are seen to be flying nose on (Chapter 3, Photograph Nos. 3.10 and 3.13). The angular motion of the bullets discharged through the countrymade firearms has been quantified in Table Nos. 3.4, 3.7(A), 3.9 and 3.10 and it is seen that the average angular movement varies from 53.6-253 revolutions/sec in case of .303, ball, Mk 7 bullets and 26.8-114.3 revolutions/sec in case of .380, ball, Mk 2 bullets. This instability has a profound effect not only on the trajectory but also on the terminal/wound ballistics effects produced by such bullets.

The tumbling bullets as depicted in the photographs are bound to lead to a variety of appearances in the wounds of entry. The wound of entry could be round, oval or elongated depending upon the manner in which the bullet presents itself at the time of impact. This observation was also made by Jauhari (53) while examining bullet holes produced by such bullets on gelatin blocks. Again, because of the high rate of angular motion of the bullets about their centres of gravity, the wounds of entry are also expected to show evidence of considerable laceration.

A spin stabilized bullet is expected to tumble only at long ranges in the terminal phase of its trajectory when the spin is reduced below a threshold figure due to air resistance. Alternately, it can depict a tumbling
behaviour after passing through an intermediate target, such as glass, panes, doors, windows, automobile body, etc. Similar phenomenon may be observed in re-entrance wounds. Further, if a bullet is deformed or becomes unstable due to ricochet (75-77), it may also cause atypical wounds. It is observed in many cases that adequate spin is not imparted to a bullet due to a variety of causes, e.g., due to worn out rifling, use of old ammunition, mismatched ammunition, ammunition stored in adverse conditions, etc. This inadequate spin makes the bullet tumble. Such a tumbling bullet may also produce keyhole entrance wounds with considerably reduced penetration on account of instability and reduced muzzle velocity. Thus a wound due to a spin stabilized bullet in the terminal phase of its trajectory or due to a bullet having passed through an intermediate target or ricocheting bullet or a bullet discharged through a firearm using old/mismatched ammunition etc. may have the characteristics of one produced by an unstable, low velocity projectile. In this connection, a historical incident draws attention. On 13th March 1917, Shaheed Uddam Singh used a 6 chambered .455 S & W revolver. He fired twice at General Dwyer, Lt. Governor of Punjab, twice at Lord Jellicoe, once at Lord Lamington and once at Sir Dane. Only General Dwyer succumbed to the fatal shots and others survived. Robert Churchill, the ballistic expert, opined that ammunition of smaller caliber had been used in an improvised manner and this resulted in unpredictable accuracy, penetration and killing power. But at that time, he had no means to demonstrate the flight characteristics of such bullets.

The high speed analysis preserved in Chapter 3 clearly show that low velocity and bullet instability could indeed be the characteristics of projectiles discharged through country made weapons. Therefore, a wound produced by a bullet discharged through a factory made weapon under circumstances discussed above could be confused with that produced by a country made firearm. Extreme care is, therefore, to be exercised in assessing the character of wound. The wound interpretation is to be guided by auxiliary information throwing light on the type
of weapon involved, presence or absence of close range phenomena, etc. Some aid in the proper reconstruction of the incident can be had from the projectile if the same is available for examination. Absence or presence of rifling marks can give vital clues regarding the type of weapon. Evaluation of bullet deformation may point towards ricochet, passage through intermediate targets, etc. The bullet instability and its consequences which may not be easily understood by the courts can be convincingly demonstrated by high speed photographs such as those recorded in the present work (Chapter 3).

**Shotgun Ejecta:**

The ejecta discharged through firearms chambered for a 12 bore shotgun cartridge present a different picture due to the differences in the constructional features of a 12 bore, K.F. cartridge. The make up of a 12 bore, K.F. shotgun cartridge is shown in Figure No.6.1. It is seen in the figure that the cartridge has no conventional bullet but there are a large number of pellets and a column of wadding. The ejecta will, therefore, consist of overshot card, pellets, undershot card, aircushion wad and overpowder card. When a shotgun is fired, the pellets along with the wadding components emerge out of the muzzle. The flight sequence of the components of ejecta has been pictorially depicted in the Photograph Nos. 3.16-3.21 in Chapter 3.

The Photograph Nos. 3.16 & 3.17 (Chapter 3) are for the standard I.D.F shotgun taken at a muzzle distance of 40 inch and 100 inch respectively. The presence of gas front in Photograph No.3.16 shows that this muzzle distance (40 inch) is within the muzzle blast range. The blast is found to be moving with a fairly high velocity of 520.5 ft/sec (Chapter 3, Salient Observations). The shots are seen to be moving en masse. While the closing disc has fragmented, the undershot card is very close to the back of the shot column. The shot column, the aircushion
wad and the other wadding components are all seen moving in the line of firing except the fragments of the closing disc which are flying both above and below the line of firing. It is also observed that the different components have acquired a small component of velocity in the vertical direction (18.6 ft/sec - 20.77 ft/sec). In the picture frames, there is a distinct evidence of increasing size of the shot column. Between the 9th and the 10th frames, it has registered an increase in diameter of 0.218 inches and 0.17 inches in the horizontal and vertical directions respectively (Chapter 3, Table No.3.11(a)).

FIGURE NO. 6.1: Schematic diagram of a longitudinally cut 12 bore K.F. Shotgun Cartridge
There is a distinct difference in the behaviour of ejecta from the countrymade Shotguns. Photograph Nos.3.18 - 3.21 (Chapter 3) depict the ejecta from countrymade Shotgun Nos. 1 and 2 at muzzle distances of 15 inch and 40 inch. It will be instructive to study them in comparison with those of the standard IOF shotgun (Photograph Nos.3.16 and 3.17, Chapter 3). The Photograph Nos.3.16, 3.19 and 3.21 (Chapter 3) were taken at a muzzle distance of 40 inches. Inspite of this, it is seen that the spread of shots is much more in case of the countrymade Shotgun Nos. 1 and 2 which have shorter but oversized barrels (Chapter 3, Table Nos. 3.1 and 3.2). Again, the velocities of the corresponding ejecta components in case of countrymade Shotguns are also seen to be lesser than those fired through the standard IOF Shotgun (Chapter 3, Salient Observations). Whelen (73) observes "In case of shotguns, the barrels at least 25 inches long are necessary to burn enough powder to give the shot the velocity needed for sufficient penetration and also to align accurately enough when thrown quickly to the shoulder". Di Maio (79) opines : "When the shotgun barrels are shortened to less than 9 inches, the shot patterns begin to open up significantly". Again the experimental findings of Richard et.al. (80), Kamaka (81) and Moreau et.al. (82) show that the weapons with the shorter barrel lengths produce larger pellet patterns and when the barrel lengths were similar, the larger caliber handguns produce larger pellet patterns". Shorter barrel lengths, oversized bore, etc. lead not only to improper burning of propellant but also result in escape of powder gas through and around the shot column in addition to leakage due to various defects in the countrymade weapon design. A reduction in muzzle velocity is, therefore, an inevitable consequence. The escape of gas through the interspaces in the shot column has a tendency to scatter the pellets. Thus the opening up of the shot pattern and reduction in muzzle velocity of ejecta as observed in case of countrymade shotguns vis-a-vis the standard IOF shotgun is fully substantiated.
Literature (83-87) is full of theoretical and experimental findings in connection with the discharge phenomena of gas, shots and wads through standard shotguns. The well established medico-legal observations (88-91) are strictly applicable to standard factorymade shotguns. But these findings do not hold good for countrymade shotguns which are used frequently in crimes in India. It is a fact that the same ejecta are discharged through their barrels but the discharge phenomena with the countrymade shotguns are found to be at variance with that of the regular shotguns. The flight characteristics of the ejecta discharged through the countrymade shotguns do not follow the established norms which are applicable in case of regular factorymade shotguns. Each firearm/cartridge combination of countrymade variety has a stamp of individuality and its performance is to be evaluated by actual experimental tests (92). The High Speed Photograph Nos.3.18 - 3.21 (Chapter 3) are a clear record of this fact.

The Honourable Courts, which are the seats of Justice, deliver judgements which rely heavily on the observations made by the authorities with respect to regular shotguns. As there is practically no authoritative work in respect of countrymade shotguns, the Honourable Court in Rajendra Singh & others Vs State case (93) wanted the results by actual test firings to see how the exhibit countrymade pistol behaves at different ranges of firing and accordingly directed the SSP, Allahabad to fire 10 shots from a 12 bore regular shotgun and from the exhibit countrymade pistol keeping the targets at various distances. The experimental findings of the SSP even though served the limited purpose of the Court could not throw any light on the total behaviour of the ejecta components fired through the standard shotgun or the countrymade pistol.
It remained silent on velocity, range, lethality, spread of shots and other trajectory parameters of the wadding components. A photographic record of the flight characteristics of the shotgun ejecta components as presented here could have been a better approach to the problem.

The High Speed Photograph Nos. 3.16, 3.18 and 3.20 (Chapter 3) were taken within the range of gas blast. The first few frames in the above photographs show the flight of fragmented parts of the closing disc. These fragments are seen moving much ahead of the gas front in all the cases. But the Photograph Nos. 3.17, 3.19 and 3.21 (Chapter 3) which were taken beyond the blast range do not show any such fragmented wad pieces because the wads failed to reach the field of view of the camera. Di Maio (94) observes: "The overshot wads which usually carry some details of the cartridge/shot are either found at the scene of crime or are embedded in the wounds". The present work shows that the closing disc could also fragment and thus the important details of the cartridge/shot might not be decipherable even if these fragments are recovered.

As mentioned earlier in case of standard IDF Shotgun (Chapter 3, Photograph Nos.3.16), the shot column is moving as a single solid projectile within the range of gas blast. The undershot card and other wads follow the shot column very closely. Smith (95) observes in connection with close range firing through standard shotguns that the contact wound caused by shotgun is a large injury often ragged because of gas tearing. Underlying destruction of tissue is great. Wads are often found in the wounds together with any other constituents of the cartridge. Upto about one yard, the wound is likely to be a single hole due to shots entering the body en masse. Bleisher (96) and Greval (97) observe similarly. It is, therefore, seen that the sequence of events snapped in Photograph No.3.16 (Chapter 3) strongly support the findings of the medico-legal experts when a standard shotgun is considered. As the wads follow the shots closely, they can enter the wound following the shots.
But these findings may not be applicable to countrymade shotguns even within the blast range. The Photograph Nos. 3.18 and 3.20 (Chapter 3) show that even at 15 inch muzzle distance the formation of single hole is not possible and the shots are seen to spread out. The peripheral shots may form satellitic holes around a central hole and the wads which closely follow the shots may or may not get embedded in the central hole depending on their direction of movement, remaining velocity/energy and area of presentation at the time of hitting the body.

In the case of standard shotguns, the absence of dispersed shot pattern is a positive proof for close range firing but the presence of a dispersed pattern in case of countrymade firearms does not necessarily mean that the firing was from a long distance as is observed with the dispersed patterns (Chapter 3, Photograph Nos. 3.18 - 3.21) formed by the countrymade shotguns. The dispersed shot patterns for close range firing through countrymade shotguns may be accompanied by charring, blackening, tattooing, etc. Taking into consideration the above facts, it is possible that a shotgun injury may sometimes lead to confusing medico-legal interpretation. This possibility stems from the fact that the injury due to countrymade shotgun at short range could be very similar to the one caused by firing a regular 12 bore shotgun from a longer distance. This calls for a closer examination of the wound. The wound should be examined for presence of charring, blackening or for any gas discharge particles, etc. It should also be searched for the presence of wadding materials. A similar situation cropped up in the case of Shiv Kumar Vs State (98) (excerpts reproduced below):

"According to the prosecution version the deceased was hit by two separate shots fired by two different accused which resulted in his death. The autopsy on the dead body of the victim revealed following ante-mortem injuries:

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1. Circular lacerated firearm wound in the area of 7 cm x 7 cm muscle deep on the back of the left wrist joint, margins are inverted.

2. Multiple circular lacerated firearm wounds in the area of 15 cm x 13 cm on the front and left side of chest.

3. Single wound 0.5 cm x 0.5 cm muscle deep in both the injuries.

Blackening and singeing of hair present and margins are inverted.

According to the opinion of doctor, the death was caused due to shock and haemorrhage as a result of ante-mortem injuries.

It was contended on behalf of the appellant that the injuries sustained by the deceased appear to have been caused by countrymade pistol and not by gun considering the nature of the injuries. It was submitted that the dispersal of the pellets in an area of 15 cm x 13 cm is in conflict with the blackening and singeing of hairs around the wounds of the deceased. It was also contended that both the injuries of the deceased are the result of one shot from a countrymade pistol and they are not the result of two separate shots from gun as stated by the witnesses. It was urged that from a distance of four to five paces, the pellets of a cartridge discharged from a gun will go en masse inside the wound and there will not be dispersal to the extent of 15 cm x 13 cm. In order to properly appreciate the
aforesaid submissions of the learned counsel for the appellants regarding the dispersal of the pellets, blackening and singeing of hairs around the wounds. After going through the post-mortem report the Ballistic Expert stated before the Court that it is probable that these injuries could have been caused by firing a countrymade pistol from a distance of four to six paces. He further stated as follows: "Singeing and scorching are nearly the same thing but they are actually the same. Burning of hair is singeing. In scorching the skin may also be involved. Scorching and singeing is dependent upon closeness of the weapon with the object. I agree that the shorter is the barrel, the greater is the dispersal of the pellets and vice versa. With a standard weapon, singeing is possible within a distance of one foot. There is no dispersal possible from a standard gun from a distance of one foot. At a distance of one foot, the pellets will enter the object en masse. In Ex. Ka 3, wounds show the dispersal of the pellets as well as blackening and singeing. Generally, it is not possible to have so much dispersal and blackening and singeing even if a hand filled cartridge is used. If both the injuries are in the same line of firing at the time of shot, then the injuries could be caused even by a single shot. If the firing is made from a countrymade pistol which has a wider barrel then these injuries could be caused by a countrymade pistol. After considering the Ballistic Expert's opinion and the argument advanced on behalf of the appellant the learned Judges held that the evidence of the prosecution was in direct conflict with the nature of injuries sustained by the deceased. The deceased died as a result of firing from countrymade pistol and only one shot was fired. The learned Judges further observed, "If a standard gun is fired from a distance of 4 to 6 paces on the object, the dispersal of pellets to the extent of 15 cm x 15 cm in area is not probable and also there would be no dispersal of pellets possible from a standard gun if the weapon is fired from a distance of one foot,
the pellets then will enter the object en masse. Moreover, we further hold on the basis of the opinion of the ballistic expert that from a distance of 4 to 6 paces, it is not possible to have so much dispersal, blackening and singeing in this case even if a hand filled cartridge is in the standard shotgun. Consequently if there is dispersal of pellets in an area of 15 cm x 13 cm with blackening and singeing around the wound it is probable that a countrymade pistol would have caused such a wound fired from a distance of 4 to 6 paces on the object."

Sometimes, because of the "billiard ball ricochet effect" due to the presence of an intermediate target (like glass pane or thick window curtain or a card board), the shots discharged through standard shotguns on the final target are seen to spread out even at close ranges (99). In these cases, the intermediate target having a single hole formation should be examined for the presence of blackening, powder particles, etc. Here also the presence of wads in the wound is unlikely whereas the possibility of the presence of particles from the intermediate target is high. Thus examination of both the intermediate and the final targets can definitely distinguish the wounds caused by a countrymade shotgun at a close range from that caused by a standard shotgun at a close range through an intermediate target.

If the body is covered by a garment and the wound is caused at a close range by a countrymade shotgun, the wound may not show the evidence of blackening or tattooing and even the wads may not be located in the wound because of the masking effect of the thick garment. The short range wound caused by a countrymade shotgun may, therefore, be confused for a long range wound caused by a standard shotgun. The covering garment, therefore, needs examination for the presence of blackening/tattooing and for presence of any embedded wadding materials or parts of the garment.
Jauhari (100) and Di Maio (101) observe that due to imperfect sealing of the bore in case of the countrymade weapons, there is escape of hot powder gases around the wadding into the shot column. This may cause them to fuse together due to heat. This fused column of shots flies as a single projectile, produces a single hole of entry and separates into individual pellets on entering the body due to tissue resistance. It is, therefore, obvious that in the above circumstances, a single hole of entry may be produced up to considerable distance. This may again be confused with a close range firing by a standard shotgun. Absence or presence of wadding materials in the wound and of blackening/tattooing around the wound (single hole) coupled with experimental tests using high speed photography may throw light on the cause of such anomalies.

As the range of firing increases to 100 inches (for standard shotgun in the present experimental firings) the wadding materials begin to separate from the shot column and so also the pellets, causing dispersion. This has been photographed in Photograph No.3.17 (Chapter 3). Spitz (102) observes: "With the close range shots up to as much as 4 to 5 feet, the shotgun charge enters the body as a single mass, producing a round defect somewhat larger in diameter than the bore of the barrel. Beyond this range the diameter of the wound increases as the shots begin to fan out and stray shots make tiny entrance wounds separated from the main defect." Mant (103) notes similarly, i.e. up to short distances, this column moves as a single unit but afterwards the components begin to disperse. But when the cartridge is fired through countrymade firearms, the distance up to which the various components move together, the rate of dispersion etc. vary considerably as is evident from the analytical data presented in Table Nos.3.15(A), 3.14, 3.15(A) and 3.16, Chapter 3.
In Photograph No. 3.17 (Chapter 3), it is seen that the undershot card is slowly taken over by the aircushion wad while moving from frame No. 4 to frame No. 9. This particular observation is strictly in line with the experimental range determination of different wads by Sinha et. al. (104) where they have shown that the aircushion wad being heavier than the undershot card has a greater range. The ranges calculated at various drops (Chapter 5, Table Nos. 5.4 - 5.9) also confirm the same.

Whelen (105) observes: "The late Philip P. Quayle of the Peters Cartridge Co., was the first to accurately record shot stringing by means of spark photography and he gave us our first accurate knowledge of the matter." He also gives reasons which influence longitudinal spread of shots i.e., "The same factors that influence the spread also influence the stringing. Briefly, the stringing is caused by the deformation of the shots while in the barrel, particularly as they pass through the cone and choke. The type of powder used and the top over-shot wad also influence stringing." It is seen from Photograph Nos. 3.18 and 3.20 (Chapter 3) that the stringing effect starts even at 15 inches from the muzzle. One can gauge the total effect of the spread of the shots in a vertical plain by the full shot pattern on a stationary target. But the effect of the spread of shots along the line of firing (stringing) can be felt if there is relative movement between the target and the shooter. Depending on the muzzle distance, velocity of the mobile target (like a running vehicle), etc., the shot pattern on a mobile target may be quite different from that received on a stationary target. Thus only the high speed photography can give a clear picture of the stringing of shots.
TRACY ORY OF PROJECTILES/WADDING

In forensic work, one has to often work out the trajectory of a projectile to ascertain its range, penetration, remaining velocity/energy and terminal ballistics effects. Such evaluations are helpful in the reconstruction of a shooting incident. This is especially so in the case of countrymade weapons whose ballistic behaviour does not follow any set pattern. It will be ideal to conduct experimental tests with the firearm involved in crime using ammunition similar to that involved in the shooting incident. Such experimental evaluations, though important, are not feasible under all circumstances. Thus, if one are to estimate the maximum range of a firearm, the location of the bullet at such long ranges will be well-nigh impossible in an experimental evaluation. It will also not be possible to measure its remaining velocity with a chronometer at all except the short ranges due to the difficulty of ensuring the passage of the bullet through the triggering screens. In all such situations, it is helpful to resort to semi-experimental methods where some initial firing parameters are determined experimentally and the rest are evaluated theoretically using the solution of the normal equations of motion. This approach has necessitated the development of suitable mathematical formalisms within the framework of established external ballistics methods. This approach was followed in Chapters 4 and 5 keeping the forensic aspect of the problem in full view.

As is evident from the muzzle velocity data of countrymade guns given in Chapter 3, the projectiles discharged through such guns, generally, possess subsonic muzzle velocity. If subsonic muzzle velocity is assumed, the velocity square law of air resistance can be straightaway used in finding the solution of the normal equations of motion. This solution has been presented in Chapter 4 on the assumption that (a) earth is flat and non-rotating; (b) there is only one fixed value of acceleration due to gravity; (c) drag due to air and gravity are the only forces acting on the projectile; and (d) there is
uniform and standard distribution of density and temperature in
the atmosphere. In forensic work, the trajectories involved are
usually short in length. Therefore, not only the above
assumptions are justified but the Siaacci approximation of a flat
trajectory holds good. This leads to considerable simplification
and it is possible to find the solution of the normal equations
of motion in an analytical form. This solution is embodied in
equations (4.1) to (4.4) given in Chapter 4 from which all
parameters of forensic interest can be easily calculated.

It may sometime be necessary to consider
curved trajectories in the subsonic velocity domain. Thus, for
example, if one were to estimate the maximum range of a
countrymade gun, the Siaacci solution will not be valid due to the
simple reason that such ranges are attained at high elevations
when the trajectory is highly curved. Therefore, Euler's solution
of the normal equations of motion has been used to take into
account the high angle curved trajectories which are necessary
for attaining the maximum range. This solution is contained in
the equations (4.5) to (4.10) given in Chapter 4 and enables one
to compute the range, time, remaining velocity, etc. at various
angles of elevation.

Both the solutions can only be used if the
value of ballistic co-efficient is known. The ballistic
coefficients of projectiles as given in literature correspond to
the circumstance under which they are flying nose on. This value
of the ballistic coefficient can not be used to evaluate the
trajectory of projectiles discharged through countrymade guns
because such projectiles are highly unstable and tumble during
the course of their flight (Chapter 3, Photograph Nos. 3.11,
3.12, 3.14 and 3.15). As the projectile tumbles, it presents an
ever changing frontal area leading to a varying ballistic
coefficient. In computation work, therefore, an average value of
ballistic coefficient is necessary to make the calculations
realistic and acceptable. In order to derive this value, recourse
has been made to Cumming's approximation in Chapter 4. According to this approximation, "Neglecting the complications due to residual spin, it can be shown that the ballistic coefficient of a tumbling bullet is approximately the same as that of a sphere of the same weight and surface area". Using this approximation, a general expression for the ballistic coefficient of a tumbling projectile has been given vide equation No. 4.11 in Chapter 4. Subsequently, as an illustration, an expression for the ballistic coefficient of a cylindro-conoidal bullet having an ogival front has been derived vide equation No.4.17 (Chapter 4). This expression has been used for calculating the ballistic coefficient of a .303, ball, Mk 7 bullet. It is seen that the ballistic coefficient of a Mk 7 bullet tumbling in a more or less random manner is .032 as compared to the literature value of 0.27 when it flies nose on. This means that a tumbling .303, ball, Mk 7 bullet, on an average, experiences about 8.4 times more resistance than when it is flying nose on. While the expression 4.17 in Chapter 4 for ballistic coefficient holds good for a cylindro-conoidal bullet having an ogival front, projectiles with other nose shapes can also be dealt similarly if the mathematical form of their nose shape is known or can be approximated.

While, undoubtedly, the projectile is meant to cause injury, it has been observed in actual cases (106 - 108) that the shotgun wadding components are also able to cause injury. This necessitates the evaluation of the lethal power of wadding components. Such a mathematical formalism has been developed in Chapter 5. Treating different wadding components as individual projectiles, their ballistic coefficients have been approximated using Cumming's approximation and then the solution of normal equations of motion based on the Siaacci assumption has been applied to obtain approximate results. An important contribution of the present work is the introduction of range wind correction in the equations of motion since it can sensitively affect the trajectory of light wadding components. The high angle trajectories of wadding components could also be considered within the framework of Euler's solution but the same
have not been dealt in the present work as they are not of any immediate forensic interest.

It is seen that the equations Nos. 4.1 - 4.10 (Chapter 4) involve numerical quadrature which can be extremely laborious and time consuming. To automate the entire procedure, both the Siacci and the Euler's solutions were programmed on the BDP-100 computer using BASIC language. This has led to an interactive programme which can be used even by a technician. The results are displayed on the video screen and are also printed as hardcopies. The convenience of using the programme can encourage a ballistician to use it routinely in day to day work without the fear of understanding the mathematical intricacies of the solutions and is, therefore, a step forward in achieving automation in firearms identification.

**Projectiles Discharged Through Firearms**

The muzzle velocity of a firearm is an important ballistic parameter. It determines the maximum velocity/energy available to a bullet because velocity/energy of a bullet decreases continually due to air resistance in the subsequent course of its trajectory. It is also significant in determining the parameters of bullet trajectory. A higher muzzle velocity/energy is conducive for a longer range and a higher remaining velocity/energy at various ranges of firing. The muzzle velocity figures of .303, ball, Mk 7 bullet discharged through the countrymade Pistol Nos. 1 and 2 (622 ft/sec, 254 ft/sec) are only 25.4% and 10.38% respectively of the muzzle velocity developed in the .303 Rifle (2446.7 ft/sec). The muzzle velocity figures of 1.380, ball, Mk 2 bullet discharged through the countrymade Revolver Nos. 1 and 2 (172 ft/sec, 234 ft/sec) are 26.4% and 35.9% respectively of the muzzle velocity developed in the .380, H & R Revolver (651 ft/sec). The muzzle velocity figures in case of the Countrymade Shotgun Nos. 1 and 2 (568 ft/sec, 556 ft/sec) are 48.8% and 47.7% respectively of the muzzle velocity.
developed in the 12 bore, IOF, Shotgun (1165 ft/sec). Similar reduction of muzzle velocity in countrymade firearms vis-a-vis their factorymade counterparts has also been reported by Nag et al. (109).

This drastic reduction in muzzle velocity/energy of the countrymade firearms vis-a-vis their factorymade counterparts is due to various factors. As the propellant is ignited, the gas produced generates pressure. The rate of burning of propellant in a cartridge is sensitively controlled by the surrounding pressure. If the required pressure is not maintained, the burning can be considerably slowed down and the propellant may even stop burning below a certain threshold pressure. The loose fit of the cartridge in the chamber, oversized barrel, small barrel length, etc. seriously hamper the burning of the propellant in a countrymade gun. There is escape of gas due to inadequate sealing, due to lack of obturation and also on account of openings and leaks due to imperfections in the material of the barrel/chamber. This results in loss of pressure and consequently, the burning of the propellant is affected. A lot of propellant, therefore, remains unburnt and a portion of the energy of propellant goes to waste. The loss of muzzle velocity due to factors mentioned above is fully borne out, if a reference is made to Table Nos. 3.1 and 3.2 (Chapter 3) where the physical parameters of the factorymade and countrymade firearms have been tabulated. It is seen that the barrels of countrymade Pistol Nos. 1 and 2 and Shotgun Nos. 1 and 2 are much shorter in length than that of the .305 Rifle and the 12 bore Shotgun respectively. The barrels of all the countrymade firearms are also oversized. The crude manufacture of the countrymade firearm and the attendant defects in mechanism, material, etc. are also evident from the Photograph Nos. 3.2, 3.3, 3.5, 3.6, 3.8 and 3.9 (Chapter 3).
Beyer (110) has given a velocity classification. The entire spectrum of projectile velocities is divided into three groups, viz., "low velocity", "medium velocity" and "high velocity". Impact velocities below 1200 ft/sec are termed as low velocities, between 1200 ft/sec and 2500 ft/sec as medium velocities and above 2500 ft/sec as high velocities. Generally speaking, the wounds are found to be relatively "cleaner" and free from the so-called explosive effect with low impact velocities. With medium velocities, they become more extensive with considerable tissue destruction and with some explosive effect. High impact velocities result in many so-called explosive wounds with a maximum destruction of tissues.

On the basis of this classification, the muzzle velocities of all the firearms (Table No. 2.3, Chapter 2) except the .303, Enfield Rifle fall in the low velocity group. The muzzle velocity of the .303, Enfield Rifle is close to the upper limit of the medium velocity group. A significant change in the pattern of injury even at close ranges is, therefore, expected when the .303, ball, Mk 7 cartridge is used in country-made firearms (Pistol No. 1 and 2). The nature of wounds caused by a .303, Enfield Rifle are well documented in literature (111-113). This rifle is known to cause explosive wounds with considerable destruction of tissues. But such wounds can not be caused by country-made Pistol Nos. 1 and 2 due to their low muzzle velocities. The wounds caused by these Pistols at close ranges can, therefore, be confused with those caused by the .303 Enfield rifle at long ranges where the remaining velocity of the bullet reduces so much that it matches the muzzle velocity of the country-made Pistols. A grave possibility of confusing medico-legal interpretation automatically arises unless evidence is adduced to prove that a country-made firearm and not a regular .303 rifle was used to fire the .303, ball, Mk 7 cartridge. Lack of rifling marks on the bullet and presence of close range phenomena around the wound/ on the clothing can help in resolving the issue. In
case of other firearms, it is noted that the muzzle velocities of both factory-made and country-made firearms fall in the low velocity group. While a drastic change in the pattern of injury is not expected, the bullets discharged through country-made firearms are expected to register lower penetration and lesser tissue destruction as compared to their factory-made counterparts due to lower muzzle velocity and bullet instability. In this case also, evidence of the use of factory-made weapons can be provided through an examination of the bullet which in the case of country-made weapons is expected to be devoid of rifling marks. The range of close range phenomena is also expected to change in case of country-made weapons with more evidence of unburnt/partially burnt grains of propellant. In case of Shotgun, change in the spread of shots can be a useful indicator. This will be discussed later in course of discussion relating to shotgun ejecta.

It is stated that a minimum of 125 - 175 ft/sec velocity is needed for just penetrating the human skin and, similarly, a minimum velocity of 200 ft/sec is needed for the penetration of bone. Projectiles with velocities less than about 250 ft/sec are not expected to cause more than a trivial injury on a clothed subject (114,115). In the light of the above velocity thresholds, a reference to Table 3.3 (Chapter 3) suggests that the muzzle velocities of country-made Pistol No. 2 (250 ft/sec) and country-made Revolver Nos. 1 and 2 (190 ft/sec and 310 ft/sec respectively) are such that these firearms are not expected to prove as lethal agents of any consequence even at close ranges of firing. The other firearms have muzzle velocities which may cause injuries of varying degree depending upon the shooting distance.

While no clear cut casualty criterion is available in literature, several figures for the minimum energy
to cause a disabling wound have been advanced by various authors (116, 117). It is generally accepted that 58 ft. lb. figure is the best of all. It is observed that only Pistol No. 1 has this muzzle energy. The muzzle energy of others falls below this threshold.

It will be interesting to evaluate the trajectory parameters of .303, ball, Mk 7 bullets discharged through countrymade Pistol Nos. 1 and 2. It is noted from Table No. 4.2 (Chapter 4) that the initial energy of 149.95 ft. lb. of bullet discharged through Pistol No. 1 is reduced to the threshold figure of 58 ft.lb. at a distance of 271 ft. Its remaining velocity reaches the threshold figure of 200 ft/sec at a distance of 639 ft. The lethal potentiality of this firearm is, therefore, expected to suffer considerably beyond 271 ft and beyond 639 ft, it is expected to cause nothing more than a trivial injury on a clothed subject. In so far as Pistol No. 2 is concerned, its initial energy is itself less than 58 ft.lb. (Table No. 4.1, Chapter 4). At a distance of 135 ft, even its velocity reaches the threshold figure of 200 ft/sec (Table No. 4.2, Chapter 4). Even otherwise, its muzzle velocity (254 ft/sec) is also very close to the threshold figure of 250 ft/sec for a trivial injury.

Table No. 4.1 (Chapter 4) gives the various parameters of the trajectory at selected drops. It might be interesting to compare the remaining velocities/energies of the .303, ball, Mk 7 bullet at selected ranges also. This can be done with the help of the same computer programme which was used to derive the data in Table 4.1 by making the range as an independent variable. Calculations made on this basis are given in Table No. 6.1. While the two pistols are no match to the .303 Enfield rifle, the Pistol No. 1 seems to be superior to Pistol No. 2 as a lethal weapon at the corresponding ranges of firing due to higher remaining velocities/energies.
TABLE NO. 6.1: Velocity and Energy Figures of Tumbling .303, ball, Mk 7 Bullets Discharged through Countrymade Pistol Nos. 1 & 2 at Muzzle Distances of 25, 50, 75 and 100 ft.

<table>
<thead>
<tr>
<th>Range (ft)</th>
<th>Pistol No. 1</th>
<th></th>
<th>Pistol No. 2</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Velocity</td>
<td>Energy</td>
<td>Velocity</td>
<td>Energy</td>
</tr>
<tr>
<td></td>
<td>(ft/sec)</td>
<td>(ft.lb.)</td>
<td>(ft/sec)</td>
<td>(ft.lb.)</td>
</tr>
<tr>
<td>25</td>
<td>595</td>
<td>137</td>
<td>243</td>
<td>22.9</td>
</tr>
<tr>
<td>50</td>
<td>569</td>
<td>126</td>
<td>233</td>
<td>21</td>
</tr>
<tr>
<td>75</td>
<td>545</td>
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<td>222</td>
<td>19</td>
</tr>
<tr>
<td>100</td>
<td>520</td>
<td>105</td>
<td>213</td>
<td>17.6</td>
</tr>
</tbody>
</table>

A reference to Table No. 4.3 and 4.4 (Chapter 4) shows that the maximum range attained with Pistol No. 1 is very close to 1191 ft as compared to 661 ft of Pistol No. 2. At these ranges, their remaining velocities (44 ft/sec, 53 ft/sec) and energies (5.26 ft.lb., 4.11 ft.lb.) make them insignificant as lethal weapons. This is in clear contrast to the .303, Enfield rifle whose maximum range is reported to be 4 miles (118) and which is very effective at ranges corresponding to the maximum ranges of Pistol Nos. 1 and 2.

It is thus seen that the mathematical formalism developed in Chapter 4 can be effectively used to jot down the trajectory of countrymade weapons and also interpret their wounding and lethal effects within the limitations of the various casualty criterion available in literature.
Trajectory of Wadding:

The ballistic parameters of interest are the distance travelled by the wadding components in the horizontal plane, the horizontal component of remaining velocity and the total remaining energy. The distance travelled in the horizontal plane enables one to ascertain the probable position of the shooter. The other two parameters are intimately connected with the penetrating capability and the wounding power of the wadding components. In addition, the angle of attack which in the present investigation is also the angle through which the tangent to the trajectory turns enables one to examine the validity of the Siaaggi assumption of a flat trajectory at various ranges of firing. The Siaaggi assumption is at the heart of all the computations and the reliability becomes less and less as the validity of this assumption begins to be questioned. The wind velocities used, 10 ft/sec represents a gentle pleasant breeze, 20 ft/sec quite a strong breeze and 30 ft/sec, a very strong wind. Range winds have been assigned positive or negative values depending on whether or not they are with or against the firing direction.

The angle of attack figures in Table Nos. 5.4 - 5.9 (Chapter 5) clearly show that a positive wind has an effect of straightening the trajectory and a negative wind has the effect of making it more curved. The change in the curvature is dependent on the magnitude of the wind. For example, the angle of attack at a drop of 2 ft in case of the undershot card (Table 5.4, Chapter 5) is found to be \(-9.88^\circ\) in the absence of wind. As the wind velocity increases to 30 ft/sec, the angle of attack increases in magnitude to \(-6.03^\circ\). For a negative wind of the same magnitude, the angle of attack decreases to \(-26.44^\circ\). The same pattern is repeated in case of other components of wadding.
It is observed from Table Nos. 5.4 - 5.9 (Chapter 5) that the distance travelled by the different wadding components at a particular drop is dependent on the wind velocity. A wind in the direction of firing enables the wadding to be carried to a longer distance, with a corresponding reduction with a contrary wind. At a velocity of 30 ft/sec in the direction of firing, the increase in range at a drop of 4 ft as compared with "NO WIND" conditions is found to be 25%, 27.9% and 32.1% in case of undershot cards (Chapter 5; Table Nos. 5.4, 5.6 and 5.8 respectively) and 18%, 27.6% and 24.3% in case of aircushion wad (Chapter 5; Table Nos. 5.5, 5.7 and 5.9 respectively). For a negative wind velocity of the same magnitude, the results are not reliable with respect to undershot card because the angle of attack values (Chapter 5; Table Nos. 5.4, 5.6 and 5.8) suggest a steep departure from the Siaucci assumption of a flat trajectory. In the case of aircushion wad, the decrease in range is found to be 17.1%, 26% and 24.3% (Chapter 5; Table Nos. 5.5, 5.7 and 5.9). There is not any steep departure in the angle of attack figures from the Siaucci limits.

Jauhari et.al. (119) had made theoretical computations of wad trajectory without using wind correction. They compared the theoretical computation figures with those reported by Sinha et.al. (104). Only some measure of agreement could be found and the discrepancy was ascribed to various factors. Sinha et.al. conducted the firings at wind speeds of 10-15 knots, i.e., between 17-25 ft/sec approx. with an average velocity of 21 ft/sec. We may now compare our calculations for the distance travelled by the wadding for 20 ft/sec range wind with those of Sinha et. al. (Table 6.2). The figures taken from Sinha's experiments relate to those firings in which the wadding components were recovered intact. The figures in Table No. 6.2 once again show that there is only some measure of agreement. Other factors contributing to the discrepancy may be the accuracy of the determination of wind velocity by Sinha et.al., variation in wind velocity and uncertainty in their final location of the wadding components.
TABLE NO. 6.2: Comparison of Experimental and Theoretical Results

<table>
<thead>
<tr>
<th>Wadding Components</th>
<th>Horizontal Distance Travelled (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experimental (104)</td>
</tr>
<tr>
<td>Mean Range Wind (ft/sec)</td>
<td></td>
</tr>
<tr>
<td>+21</td>
<td>-21</td>
</tr>
<tr>
<td>Aircushion Wad</td>
<td>110-150</td>
</tr>
<tr>
<td>Undershot Card</td>
<td>35-60</td>
</tr>
</tbody>
</table>

When the projectile strikes a vertical target, the horizontal component of the projectile velocity is consumed in penetration. The threshold velocity required for skin penetration has been reported to be 125 - 175 ft/sec (110). A review of velocities in Table Nos. 5.4 - 5.9 shows that except for the aircushion wad and that too at a drop of 1 ft in case of Shotgun (IDF) (130 ft/sec) and countrymade Shotgun No. 1 (125 ft/sec) with a range wind of 30 ft/sec, the other figures are well below the threshold.

The remaining energy figures in Table Nos. 5.4 - 5.9 (Chapter 5) seem to be totally insignificant in the light of 58 ft.1b. criterion. Thus none of the wadding components can be wounding agents of any consequence at the ranges corresponding to the drops of 1, 2 and 4 ft.
Since the horizontal component of projectile velocity will continuously decrease due to air resistance, a situation can arise when this component may become negative with a sufficiently strong negative range wind. This would mean that the projectile will reverse its course and begin to move towards the shooter. Table No. 5.8 (Chapter 5) shows that for an increase of drop from 2 ft to 4 ft with -30 ft/sec wind velocity, the horizontal component of the remaining velocity of the undershot card decreases from 15 ft/sec to 2 ft/sec. The same Table also shows that for a drop of 4 ft, as the wind velocity increases from -20 ft/sec to -30 ft/sec, the horizontal component reduces from 12 ft/sec to 2 ft/sec. Thus, at drops higher than 4 ft or under the condition of still higher values of wind velocity (against the direction of firing) or the wads getting torn into smaller pieces (resulting in still lower ballistic coefficients), there will be a possibility for the reversal of the projectile path. Such an occurrence has been reported by Sinha et al. (120) where split closing disc was found behind the point of discharge when the firing was against a wind of 10 - 15 knots. However, it can not be ignored that the computations are of doubtful value when the angle of attack is such that it is difficult to justify the assumption of a flat trajectory.

All the computations were carried out on the basis of a value of ballistic coefficient derived on the basis of Cuming’s approximation. To test the validity of this approximation, ballistic coefficient of aircushion wad was separately estimated using high speed photography (details in Appendix 1). The value of ballistic coefficient was found to be 0.0029645. It is seen that the value of ballistic coefficient as derived by high speed photography is quite close to that determined by Cuming’s approximation (0.002054). The discrepancy in the theoretical results and those of Sinha et al. (104) can not be ascribed at this stage solely to deficiencies in the
formalism because the accuracy of the results of Sinha et al. is not known. The best way will be to conduct fresh experiments under controlled conditions and then compare the theoretical and the experimental results. Such a comparison might be expected to provide a firmer basis for isolating the factors responsible for the discrepancy.

CONCLUDING REMARKS

The laboratory work in the field of Forensic Ballistics presents a scenario where a firearms expert is engaged mostly in establishing linkage of fired bullets and cartridge cases with the suspect firearms using the celebrated Comparison Microscope with auxiliary facilities like bullet recovery box, travelling microscope, etc. While this conventional examination is important, there is a need for the experts to enter and experiment in the related areas of internal, external, terminal and wound ballistics for a proper reconstruction of the shooting incident. The subject, therefore, calls for the introduction of modern instrumental and mathematical techniques. Instrumental techniques based on sophisticated technology and computer data processing have already shown their potential for easy adaptation. It is for the firearms experts to harness the fruits of modern technology for the investigation of crime. While other disciplines of forensic science have been quick to embrace the new ideas and modernize their laboratories, firearm laboratories still wear a primitive look which can only be changed by initiative and experimentation. The present thesis has highlighted the practical applications of computer aided analysis and high speed motion picture photography in day to day investigation of firearm cases. It has also brought to fore the possibility of using the methods of external ballistics in conjunction with a computer for routine investigation of criminal cases.
While the present work can only be considered as a modest contribution, it is hoped that the firearms experts in India will take the lead in enlarging their work facilities by achieving greater and greater sophistication in the years to come. Flash X-ray technique and Scanning Electron Microscopy could be useful additions to the armoury of a firearms expert. Introduction of "Computer Man" programme (121) in the curriculum of forensic work will be another step forward in achieving greater objectivity in assessing the wounding power of projectiles.