CHAPTER - 2
LITERATURE REVIEW

2.1 INTRODUCTION:

In recent years, the foundry industry has been forced to take an increasing interest in reclaiming sands used in moulding and core making processes. This is especially applicable to sands bonded by the various chemical binders such as sodium silicate, resins and air setting oils, where the base sand needs to be relatively pure in order to achieve predictable setting times, strength, hot strength, refractoriness etc. Consequently it has been the practice to use virgin sand for each new mix and to dispose off the used sand, thereby adding considerably to the cost of the process.

Foundries have become more and more interested in the possibilities of reduced operating costs, by conservation and recycling of materials. Foundry sand has come in for its share of developmental work for the purpose of determining the most suitable method of recovering waste and making it repeatedly useful. Although sand is one of the most abundant materials, we all know that industry's demand for quality castings necessitates the use of a sand that is not locally available; and in fact it may not be available in nature and may require some degree of processing and recycling. With the trend towards total quality control many foundries have insisted on properly classified sand and are prepared to pay a premium as well as high transportation costs in order to have the ideal sand available for their use.

It is not logical, having spent money and energy in obtaining the proper sand, that the sand should be discarded after going through only one cycle of the casting process. For this reason reclamation of waste sand has great value for foundry management; because
firstly, it can make use of sand at a lower cost than new sand, and secondly, excellent control can be maintained over the properties of the sand.

2.2 IMPORTANCE OF RECLAMATION OF FOUNDRY SANDS:

2.2.1 Definitions of Sand Reclamation:

Sand reclamation is defined by the AFS sand reclamation and reuse committee [80-s] as "the physical, chemical or thermal treatment of a refractory aggregate, to allow its reuse, without significantly lowering its original useful properties as required for the application involved" (1). According to Sholl (2), "a successful and effective sand reclamation system must provide a means of disaggregating the heterogeneous mass of sand in to its original grain distribution without crushing so that there is no increase in fines content, removing all foreign matter, freeing the grains of all coatings, cooling, drying (if necessary) and returning it to original storage bins". According to Den Breejen (3), "To reclaim is to claim, or demand, the return or restoration of an object or material". Reclamation is the recovering of waste and the process of deriving usable materials from waste products. According to CIATF report (4) "Reclamation may be defined as the treatment of a used refractory moulding aggregate to enable its reuse as a moulding or core making material".

2.2.2 Need for Reclamation:

According to various authors the factors that have necessitated the need for sand reclamation are (5-8)

i) The rising cost of new sand and the need to conserve the available sources of high quality sands.
ii) The increasing cost of used sand disposal, as sites for dumping are becoming fewer, and if found are located at longer distances from foundries compared to even a few years ago.

iii) Stricter environmental controls, which make the dumping of foundry waste sand more and more difficult and expensive.

iv) The continuing high rate of consumption of new sand arising from the increasing use of non-regenerative type of binders. Without reclamation, non-regenerative type of binder processes consume very large quantities of new sand. For example, some 2 to 5 tons of new sand is consumed per ton of castings produced.

2.2.3 Justification for sand Reclamation:

Simply put, justification for sand reclamation depends upon producing a satisfactory sand that is cheaper than the cost of dumping old sand and replacing it with new sand. In other words, sand reclamation is economically justified when

i) Sufficiently large quantity of new sand is being used in the foundry as reclamation plant cost may be difficult to justify where new sand usage is low. However, where expensive sands like Zircon sand is used, reclamation becomes inevitable.

ii) New sand costs are higher than average, due to the remoteness of the foundry from the sand source.

iii) Dumping of old sand is difficult and expensive due to governmental regulations.

iv) One base sand is used in the foundry and the sands from different binder system should be separable.

2.2.4 Functions of Sand Reclamation Systems:

According to several investigators (9-13), a good sand reclamation system should perform the following functions:
i) Removal of lumps and tramp metal.

ii) Reduction of inert and organic material to an acceptable level.

iii) Reduction of the level of dead and active residual clay.

iv) Deliver reclaimed sand with a grain distribution meeting the specifications of new sand.

v) Removal of fines to an acceptable level.

vi) Removal of the coating from the sand grain uniformly.

vii) Delivery of reclaimed sand with comparable performance characteristics to new sand in the dry condition.

viii) Delivery of reclaimed sand which produces quality castings.

### 2.2.5 Debit Side of Reclamation:

According to several investigators (14-16) the debit side of reclamation are:

i) Capital cost of the whole reclamation plant with adequate depreciation allowance.

ii) Full costs of maintenance and repair of equipment.

iii) Full operational costs associated with the running of the plant.

iv) Plant yield, i.e., sand losses during reclamation.

v) Level of utilization of the reclaimed sand, i.e., the proportion of reclaimed sand that can be used successfully in moulding and core making mixes.

### 2.2.6 Credit Side of Reclamation:

According to several investigators (14-16) the credit side of reclamation are:

i) Savings from the reduced purchase of new sand.

ii) Savings in loading, transport and disposal of used sand.

iii) Possible cost savings due to the reduction of in plant handling and storage of new and old sands.

iv) Possible cost savings due to reduced binder requirements.
v) Savings in capital and operational costs where the reclamation unit replaces the function of a mechanical knock-out e.g. reclaimed in shot blast units.

2.3 FACTORS AFFECTING RECLAMATION:

According to Shanks (17) and Couture (18) the factors which affect the build up of residual binder and the extent of reclamation are

i) Sand to metal ratio

ii) Pouring temperature of the metal

iii) The initial binder content

iv) New sand addition

v) Section thickness of the casting

vi) Efficiency of reclamation plant

vii) Presence of core wastes

viii) Treatment before reclamation

ix) Type of sand used

x) Binder system used and

xi) Left out contaminants.

2.4 EFFECT OF RECLAMATION ON SAND:

According to Clifford (19), Mac Donald (20) and Tony Suschil (21) the effects of reclamation on sand are

i) Binder build up

ii) Build up of other unwanted materials

iii) Catalyst and nitrogen build up in the case of organic resin bonded sand

iv) Changes in shape of grains
v) Changes in sieve grading.

In sand reclamation any initial period of success is invariably followed by a progressive deterioration in workability and casting finish with the passing of time.

According to Clifford (19), the progressive deterioration results from the accumulative effects of physical changes (i) within the sand mass as a whole and (ii) upon the surfaces of individual grains. Over a period of time, a progressive change in grain distribution results in more and more fines becoming dispersed throughout the matrix containing more and more out size grains (Figure 2.1).

Another important physical property change with respect to individual sand grains and their contribution to mass deterioration is the creation of a "pickle" sand grains; grains having surfaces covered with wart-like projections because of small particles becoming embedded in the old bond coatings. Such projections not only serve to greatly increase the total surface area of each grain but, by interfacing with the movement of one grain past another, the projections decrease mass flowability and response to ramming energy. When the resistance offered by one or two grains is multiplied by thousands of grains, one comes to understand why old used sands are so difficult to ram into compact uniform mould surfaces. Further, any attempt to use increased ramming energy simply transfers trouble from the grains to the sand mass as a whole. As ramming energy increases, more particles are broken from the "shells" of old bond, more fines are created and the sand mass suffers accordingly (Figure 2.2).
Fig. 2.1 GENERALIZED COMPARISON OF GRAIN DISTRIBUTION REPEATEDLY USED SAND VS ORIGINAL NEW SAND

ARTIFICIALLY ENLARGED OLD SAND GRAINS ON COARSER SIEVES

USED

SHELL FRAGMENTS

% RETAINED

SIEVES SIZES

RECLAMATION AND REUSABILITY STUDIES ON CO₂ - SODIUM SILICATE BONDED SANDS FOR FERROUS FOUNDRIES.
Fig. 2.2 LAYERED COATS OF BOND AND FINES BUILD UP ON THE ORIGINAL SAND ALTERING BOTH ITS SIZE AND ABILITY REBONDED
2.5 RECLAMATION PROCESSES:-

A considerable variety of processes and equipment are in use for the recovery and reclamation of foundry sands. The earliest designed plants in use are wet reclamation plants associated with high pressure water jet methods of cleaning castings. The most recent developments are those plants incorporating vibration hoppers and vibration attrition for the reclamation of resin bonded sands; these latter reclamation plants are also the most numerous (4).

A number of patents have been filed and plants proposed for the reclamation of sands from mixed binder systems either for use with one foundry site or for use as a regional plant for processing of sands from foundries in that region. The choice of the most suitable plant will depend to some extent upon the binder system of the sand. More importantly, it will depend upon economic, environmental and conservation factors. In future years it may be the least energy consuming process. What ever may be the type of reclamation it needs a crushing step to break down and particulate the shakeout sand into individual grains of sands (<20 mesh) suitable for crushing and classifying (22).

The various reclamation processes now in practice are:

1. Wet reclamation
2. Dry reclamation
3. Thermal reclamation and fluidized bed reclamation
4. Chemical reclamation
5. Combined system.

2.5.1 Wet Reclamation:

Wet reclamation is generally considered as more useful for the reclamation of sands with synthetic binders than for sand with natural binders. According to Comite
Internationale Des Associations Techniques De Fonderie (CIATF) wet reclamation (23) can be successfully applied for the reclamation of sodium silicate bonded sands. There are several methods of sand reclamation using water as the conveying and scrubbing medium (24). All of them follow approximately the same sequence of operation although the equipment involved differ in design, efficiency and maintenance cost.

There are so many layouts for wet reclamation system as reported by Den Breejen (3), CIATF (4), Rohr (5), CIATF (23), Waclan Sakwa (24), Roberts (25), Will (26) and Zimna Wada (27).

The flow sheet of a typical wet reclamation plant used by Rohr (5) is shown in Figure 2.3. The pilot reclamation plant used for about 15 years by Will (26) is shown schematically in Figure 2.4.

In order to follow the schematic diagram, the component parts are described. The lump breaker is a rotary barrel having a center section of a perforated plate. The waste foundry sand is introduced into the lump breaker and wet down. Sand and water pass through the perforations while lumps are tumbled in the barrel and are abraded to individual sand grains. After passing through the perforations the slurry is screened over a vibrating unit equipped with a 6 mesh screen deck.

After screening, the sand and water slurry is pumped to the primary classifier. The purpose of this classifier is to remove undesirable free fine material in order to increase the scrubbing efficiency. The amount of fines removed depends on:

i). The retention time and velocity in the classifier tank.

ii). The size of bottom orifice opening.

iii) The amount and velocity of counter flow water.
The scrubber impeller operates at 1750 rpm. The scrubbing action is obtained through impingement of the high velocity stream of slurry against a slower moving stream along the outer circumference of the scrubber. Circulation is maintained in a vertical motion as well as in the direction of travel of the impeller, thereby reducing the possibility of short-circuiting through the scrubber. The impingement of sand grains against each other produces a friction which is sufficiently great to properly scrub the individual sand grains. The impeller is a simple paddle type which can be cast in a foundry. It requires no machining and can be easily replaced by raising the motor supported shaft. The impeller is the only high wear part of the scrubber and has a life of 8 to 16 hours. After scrubbing, the sand flows into the second sand transfer tank from where it is pumped to the secondary classifier. The sand then flows downwards into the secondary storage bin and then to the dewatering filter. Maximum dewatering is carried out before drying, in order to reduce fuel cost. From the dewatering cylinder, it is fed to a dryer by a screw feeder.

The wet reclamation process has not undergone noticeable improvements for many years. One aspect that has been improved upon is the drying of sand (26). 10 tons of water is required to reclaim 1 ton of sand. Taylor (28) reported that the cost of the reclamation system is £40,000 for (1£= Rs 43) reclaiming 2000 tons / annum and the cost of reclaimed sand is around £2.0 per ton (or about Rs 86 per ton). The drawbacks in wet reclamation according to CIATF (23) are the following:

i) Higher investment and operating cost.

ii) Necessity of removing water from the reclaimed sand and energy required for drying and

iii) High water consumption and the need for water processing.
Figure 2.3 Wet Scrubbing sand Reclamation System.
Fig. 2.4 SCHEMATIC OUTLINE OF THE WET METHOD PILOT RECLAIMING UNIT LEGEND.
1. LUMPBREAKER, 2. SAND SUMP TANK, 3. SAND PUMP,
4. PRIMARY CLASSIFIER, 5. SCRUBBER FEED TANK,
6. SCRUBBER, 7. SAND PUMP TANK, 8. SAND PUMP
9. SECONDARY CLASSIFIER, 10. FEED TANK,
11. DEWATERING CYLINDER, 12. SCREW FEEDER, 13. DRYER.
2.5.2 Dry reclamation:

According to Henry W. Zimna wada (29), the dry sand reclamation is carried out with two objectives. a) To loosen and peel off the coatings through the impact and b) to eliminate coating debris by entraining it in slow moving air and trapping it in a dust collector. Dry sand reclamation tends to reduce the angular projections of individual grains. The rounding of grain contours contributes to better sand flowability. The scrubbed sand surface seems to have better adhesive quality, and consequently the bonding material needed is lesser. Reclaimed sands are clean except for residual material located in the crevices. According to CIATF (4) there are three different types of dry mechanical reclamation namely i) pneumatic scrubber ii) Mechanical scrubber and iii) Shot blast reclamation.

2.5.2.1 Pneumatic Scrubber:

The total dry reclamation system with pneumatic scrubber is schematically illustrated (24) in Figure 2.5. The sand first passes over a magnetic pulley to remove magnetic particles. It then enters a breaker screen to break up the lumps. The lumps that are left may be discarded or passed through a crusher. The sand that passes through the breaker screen is placed on a scalping screen to remove any undesirable coarse material. It next enters the air-sand scrubber unit where the sand grains are repeatedly picked up and impacted against each other to scrub off the coating. The sand grains travel to an outlet that discharges them into an air separator, where the fines are removed by the flow of air.

The principle of operation (30) of a pneumatic sand reclamation unit is very simple and is depicted in Figure 2.6. An air blast from a turbo blower enters the blast tube, in combination with the sand to be cleaned. The sand to air ratio is governed by (i) the distance A-B from air nozzle to the bottom of the blast tube and by (ii) the tube blower gate.
The air sand mixture is propelled upwards within the confines of the blast tube, causing the grains to abrade against each other. When the sand reaches the top of the tube, the target directs the sand either back into the same cell for further processing or into a gravity slide which directs it to the next cell. This cycling continues until the sand enters the discharge chute at the exit end of the reclaimer. The attrition and impact inherent in the process not only separates multiple grain clusters, but also removes carbonaceous coatings and other debris from the grain. The fines produced are separated and drawn away by the flow of air to the dust collection chamber. The degree of cleanliness of the reclaimed sand is dictated by the following three factors: i) The speed at which the sand passes through the individual cells. ii) The volume flow rate of air from the turbo blower. iii) The suction drawn from the dust collector into the reclaimer cabinet.

The various benefits of reclaiming sodium silicate bonded sand by pneumatic reclamation is reported by Barbara (13), Matt Granturd (31) and Wallace (32). Report of working group P7 on sand reclamation (33) at U.K (constituted by the Institute of British Foundrymen) states that plants can be built in any capacity from 0.5 ton/hour upwards using a battery of cells. For example, a 1 ton/hour unit may have 2 cells, and a 20 ton/hour unit 40 cells. The throughput for each cell varies from 227 kg/hour to 907 kg/hour depending upon the users requirements. Plant yield can vary from 75% to 90% and this factor must be taken into account when assessing the economics of reclamation. Many investigations were carried out on pneumatic sand reclamation by Daryl (34), Zimnawoda (27) and Clifford E. Wenninger (35). According to Report of commission 1.4 (4) the amount of sand available for re-use from the pneumatic reclaimer may be lower than that of other mechanical systems and the yield is lower in pneumatic reclamation system...
Fig. 25 DRY RECLAMATION SYSTEM
Fig. 2.6 SCHEMATIC OF AN INDIVIDUAL PNEUMATIC CELL
2.5.2.2. Mechanical Scrubber:

There are two types of mechanical scrubber available: They are i) Horizontal centrifugal scrubber and ii) Vertical scrubber. Among many mechanical reclamation systems reported (2,3,7,14,29,36,37, 38,39), the system reported by (36) Michael Zartkoff is shown in Figure 2.7.

It is a vertical mechanical scrubber. Sand enters the center of the impeller and is thrown upward at a target plate. Attrition takes place as the sand hits the target. The sand falls away and exits into an air wash separation, where the fines are removed from the sand. For additional scrubbing, this unit can also be operated in series (tandem). As compared with pneumatic scrubber, the impellers and targets are high wear parts. The units must be properly maintained to yield a consistent product. The dust collection system must also be properly maintained.

Process Controls:

In a horizontal scrubber, clean sand [crushed, with metal removed] is fed into the center of the unit and thrown against the target ring at a controlled velocity by the impeller. Some sand-on-sand attrition takes place, but the intense scrubbing occurs at the target ring. The exhaust plenum surrounds the target ring to remove dust and binder husks. These units can be arranged in sequence for additional scrubbing. Blending of the sand from the scrubbers with the new sand is very important. Blending is done to replace the sand that is lost in the casting and reclamation processes and to limit the effects of residual binders on sand grains. The sand should be measured and blended thoroughly to ensure that there are no concentrations that would cause undesirable effects on the castings. Most of the sand reclaimed from these units can be used in blends of 80% reclaimed sand to 20% new sand.

There are a number of tests that can be performed on the reclaimed sand from the scrubber. Two of the more important tests are loss on ignition and screen distribution. These tests are good measures of the operating efficiency of the classifiers. A build-up of sand on the fine screens, such as 200, 270 and 300 mesh is usually associated with an increase in loss on ignition, a problem that is most likely attributable to the classifier. An increase in loss on ignition without the accompanying shift in screen distribution will indicate that the binder removal in the screen is low and that maintenance and repairs may be required on the unit.
Fig 2.7 VERTICAL MECHANICAL SCRUBBER
2.5.3 Thermal Reclamation:

According to Rohr (5) the thermal or calcining systems remove carbonaceous coatings and organic binders by subjecting sand up to 815°C in the presence of oxygen. This type of system results in the most effective removal of organic materials from sand grains but also requires the use of fuel, unless methods are found to use waste heat from other sources at an elevated temperature. According to Linda Martin (40), the thermal reclamation system is used only as an exception rather than as a rule, because of the high capital cost of operating the plant. Thermal systems are essential where (i) Incompatible resin systems are used alongside each other and as well as (ii) thermal setting resins are used (e.g. shell).

Thermal reclamation may be carried out, either in a rotary kiln or in a multi-decked tower or in a fluidized bed heat exchanger. Typical schematic layouts of these plants are shown in figures 2.8 and 2.9 (22, 27, 41). In all the reclamation systems the sand is first broken down to 3.2 to 9.5 mm size and all possible metallic contaminants are removed. In the case of rotary kiln the sand cascades through the kiln which is generally gas fired. The temperature in the kiln is raised to 850-1000°C in an oxidizing atmosphere. The calcined sand is then cooled and subsequently sieved before returning to the cooling or storage hoppers. Other layouts of thermal reclamation system have also been reported by Barbara (13), Den Breezen (24), P7 working group on sand reclamation (33), Skubon (42), Busby (43) and Reinhard Franke (44).

In the case of fluidized bed calciner, the used sand (27) is fed into the calciner after crushing. The calciner is a refractory lined vertical furnace divided into three compartments. The sand is preheated in the top section "A", calcined in the middle one "
B", and pre-cooled in the lowest one "C". In this unit the sand flows downward and the hot gases upward. In the calciner, heat is developed and distributed by burners located on the periphery of the main section. Low pressure compressed air is passed through layers of sand. Because of this agitation, which resembles boiling of water, intimate contact between sand and hot gas is obtained and the exchange of heat is rapid. The precooling of sand takes place in the lowest bed by the passage of air through the sand. The openings of the refractory shelves are capped on the top, allowing the gases to go through, but preventing the sand from falling down.

It is reported by Vogal (45) that thermal reclamation requires energy of the order of 350-500 kwh/ton. The energy required is 244 kwh/ton for thermal reclamation at 475°C. The use of thermal reclamation is restricted because of the high capital cost and its unsuitability for silicate bonded sand.
Fig. 2.8 THERMAL SAND RECLAMATION EQUIPMENT FOR SHELL SAND WITH FLUID BED CALCINER AND COOLER
SCHEMATIC LAYOUT OF A ROTARY THERMAL RECLAMATION PLANT

SCHEMATIC LAYOUT OF A FLUIDIZED THERMAL RECLAMATION PLANT

Fig. 2.9 SCHEMATIC LAYOUT OF THERMAL RECLAMATION PLANTS
2.5.4 Chemical Reclamation:

Bunakov (46) reports that sodium silicate residues from used sand can be successfully neutralized using commercial hydrochloric acid. To find an effective method of neutralizing the sodium carbonate, Bunakov had carried out experiments using solutions of hydrochloric acid. Backing sand was prepared from used refractory sand, where the water content was kept constant, but different amounts of HCl (25 percent solution of specific gravity 1.095) were added. Aqueous extracts were prepared from the sands by mixing 6g of sand with 100 milliliters of water to determine the pH. The sand mixes consisted of 89 percent used sand, 10 percent of quartz sand, 1 percent moulding clay, 3 percent water and varying amounts of HCl (0 to 2%) were added to different sand mixes, giving permeability in the range of 50 to 120. Compressive strengths ranged from 3.6 to 5.9 N/cm² and pH value from 5.1 to 10.3.

Bunakov further verified these results with an experimental batch of backing sand prepared as before with 1 percent addition of HCl in the same concentration as before. The mix was used to make two block specimens, one of which was then coated with a facing layer of rapid hardening silicate bonded sand. A control block was then prepared in the same way using ordinary backing sand. The physical and mechanical properties, pH values and alkalinities of these mixes were as given in Table 2.1. Bunakov's observations further showed that the surface finish of the experimental castings were indistinguishable from those obtained with the control sands.
Table 2.1. Properties of backing sand mixes

<table>
<thead>
<tr>
<th></th>
<th>Neutralized with Acid</th>
<th>Ordinary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permeability</td>
<td>52</td>
<td>56</td>
</tr>
<tr>
<td>Compressive strength N/cm²</td>
<td>8</td>
<td>5.5</td>
</tr>
<tr>
<td>Water content %</td>
<td>6</td>
<td>6.0</td>
</tr>
<tr>
<td>Hydrogen Iron concentration (pH)</td>
<td>10.1</td>
<td>10.45</td>
</tr>
</tbody>
</table>

2.5.5 Combined Reclamation:

Curtis (47) investigated sand reclamation done by a combination of wet scrubbing and burning and compared it to the sand subjected to thermal reclamation alone. Norm Davey (48, 49) reported that combination of shot blasting and reclamation yielded better results when compared with the simple reclamation system. The purpose of a proper reclamation system should be the removal of all the unwanted materials and to produce a sand at affordable cost. The degree of cleanliness required in the sand would depend on the ultimate use of the sand. The advantage behind the combination system is that the materials not removed or left out in one system may be removed by the other system.

2.6 Reclamation with Reference to Binder System:-

2.6.1 Clay bonded sands:-

According to Dieter.S.Leidel (50), states that approximately four fifth of total casting production to day uses the time- honored green sand process with bentonite as binder. Green Sand reacts very differently from the no bake sand. At the sand / metal interface, the sand grain is heated to temperatures nearly identical to that of liquid metal
poured in the mould. Bentonite loses its bonding properties if heated to temperatures above 600°C. Therefore bentonite contained in these portions of the mould which, do not exceed 300°C can be fully reactivated, while bentonite in those portions of the mould, which are between 300-600°C can be partially reactivated. Only that part of the moulding material which has reached 600°C or more will be covered with a modified bentonite that cannot be reactivated as a binder. Foundries having recognized this problem add between 100 -200 kg of bentonite for each ton of metal poured, to dilute the system and compensate for the bentonite lost in the calcined layer of clay.

In the case of chemically bonded sand, the grains of sand are always covered by a completely cured layer of binder which has to be removed. However in green sand systems, only a few grains are covered by calcined bentonite but a wide majority of grains have a reactivatable bond. According to CIATF (4) commission report reclamation of clay bonded sands is carried out only when the reclaimed sand is to be re-used as a moulding sand in the same clay bonded sand system. Reclaiming green sand for core sand processes was studied by several investigators like Bastien (51), Regen (52) and Clark (53). Dry pneumatic scrubbing or wet reclamation and drying have been reported as being suitable for clay bonded moulding sands to be reused in the same clay bonded system (4). The reclamation system proposed by Clark (53) is a 0.5Ton/hour unit consisting of an indirectly heated rotary kiln, a rotary sand cooler, a pneumatic scrubber and classifier followed by a second identical rotary kiln, rotary sand cooler and pneumatic scrubber with classifier. The system proposed is effective in reclaiming clay bonded sands for reuse with a chemical binder system.
2.6.2 Resin bonded sands:-

For the purpose of reclamation the resin bonded sands are classified as i) Shell and hot box sands and ii) No bake sands. Extensive studies on reclamation of resin bonded sands have been carried out by CIATF (4), Wallace D.Huskonen (32) working group P7 on sand reclamation (33) at U.K (constituted by the Institute of British Foundrymen), Busby (43), Janagan (54), Stevenson (55), Sharp (56), Wotton (57) and Ryder (58). These investigations have proved that resin bonded sands could be effectively reclaimed by dry attrition methods with some air classification or by thermal method.

According to the report of working group P7 (33) wet reclamation is not at all carried out for resin bonded sands. This would be uneconomical compared to mechanical methods and inadequate compared to thermal methods.

2.6.2.1 Thermally cured sands -Shell process and Hot Box process:-

Reclamation of this group of sands can only be carried out effectively by thermal incineration at temperatures above 800°C. No foundry is known to be reclaiming hot box sands as these are normally used for core making and are lost into the moulding sand system. A number of foundries are known to reclaim shell sand to recoating quality by thermal incineration methods.

2.6.2.2 Cold setting resin bonded sands:-

These sands are effectively reclaimed by dry attrition methods with some air classification or by thermal methods. The binder on the used sand is removed sufficiently to enable the reclaimed sand to be reused. Reclaimed sands may be re-used in mixes containing upto 100% reclaimed sand. In practice 100% yield in reclamation is unlikely due to sand losses. The limit on reuse will also depend upon the tolerance of the particular binder and cast metal, for the residual contaminants present in the reclaimed sand.
It may be necessary to change the resin binder and the catalyst used when adopting sand reclamation. With continuous recycling of used sand a build up of nitrogen from the resin may cause problems of pin hole porosity or fissuring in the casting. Nitrogen may be controlled by a change to a low nitrogen or to a nitrogen free resin.

Phosphoric acid catalyst may result in a build up of phosphates and show a reduced strength development in the remulled sands, while with paratoluene sulphonic acid (PTSA) catalyst, improved strengths may be obtained when using reclaimed sand.

The most common types of organic resins which are suitable for reclamation are:

i). Acid catalyzed furan and phenolic no-bakes.

ii). Alkyd oil urethane no-bakes.

iii). Phenolic urethane no-bakes.

The most commonly used organic resins in the Acid catalyzed furnace and phenolic no bake are

a. Furfuryl alcohol / urea formaldehyde [FA/UF].

b. Furfuryl alcohol /phenol formaldehyde [FA/PF].

c. Furfuryl alcohol /phenol /urea/ formaldehyde [Copolymer].

d. Furfuryl alcohol /formaldehyde [FA polymer].

e. Phenol /formaldehyde [PF polymer].

The most commonly used catalysts with these resin systems are

a. Orthophosphoric acid [65-85%]

b. Paratoluene Sulphonic acid (PTSA)

c. PTSA or Orthophosphoric acid modified with sulphuric acid (mixed acids).

d. Xylene Sulphonic acid (XSA).
Alkyd oil urethane no-bake sands binder system consists of an alkyd resin (namely pentaerithritol and isophthalic acid), an air drying component (usually linseed oil) and a drying catalyst (such as sodium perforate or cobalt napthalate). The binder addition to sand is usually 2.5% and the hardener needed is about 20% of the binder addition. The hardener is isocyanate, toluene isocyanate, methylene di iso cyanate.

Phenolic urethane no bake is introduced during 1970's and pepset is a typical commercially used binder based on phenolic urethane binder system. Part I of a pepset contains a phenolic resin, part II is a liquid catalyst and part III is isocyanate component.

2.6.3 Oil bonded sands:-

Oil as a binder has many advantages like easy core making procedure, low cost and ready availability. According to BCIRA it has certain disadvantages like the need for heat source during curing, and high gas evolution (59). Gibbons (60) states that crushing, calcining and wet scrubbing appears to be the most effective set of processing steps, compared to crushing, calcining and pneumatic scrubbing.

2.6.4 Sodium Silicate bonded Sands:-

CIATF (4) committee report states that the effective reclamation of silicate bonded sands and their re-use is more difficult to achieve than for resin bonded sands. Leidel (61) states that Sodium Silicate is an inorganic binder, it can not be burned off. Therefore the removal of residual Sodium Silicate binder from the sand grain surface can be accomplished by attrition only. Leidel also states that sodium silicate bonded sand has very attractive properties considering the requirements imposed or the foundry Industry today. It is more readily acceptable for disposal than any of the organic (hydrocarbon)
bonded sands, and it offers zero carbon pickup, which is an attractive feature for steel foundries.

Mac Donald (64) also lists the advantages of silicate bonded sands which have a number of advantages over the organic binder sands in foundry operations:

i). They are pollution free. (No gas or smoke is created during pouring and shake out. There is nothing in the sand to burn)

ii). These sands are nitrogen free.

iii). They are not toxic to the skin and have no obnoxious odour

iv). Moulds made from these materials are rigid and stable and consequently the castings are relatively defect free.

v). Silicate sands have the lowest binder cost.

Nicholas (62) states that wet and dry systems are currently in use for reclaiming used CO₂ processed sands. Experience suggests that higher proportions of used sand can be reclaimed from a wet process (which washes, scrubs, grades and dries the sand) than from a dry process (which relies on crushing and grading alone). However, Leidel (61) specifically states that dry processes only are financially viable and not the wet ones. Lissel (63) states that when considering sodium silicate the problem of binder residue becomes more pronounced. Sodium silicate remains on the surface of the reclaimed sand grains, acts as a nucleating agent for water glass added in rebonding, and leads to premature hardening of the sand. A thorough clearing of the grains in the reclamation process is therefore important. Sodium Silicate bonded sands are therefore more difficult to reclaim than furan bonded sands.
According to several investigators the advantage of reclamation process are (62,64)

i) Little or no special equipment is required when the process is first adopted. The sand mixtures can be prepared with orthodox mixing plant while patterns and core boxes require little modification.

ii) High rates of mould and core production are possible from single sets of patterns and core boxes. Rapid turnaround of pattern equipment results from the facility either to strip in the green state or after faster hardening with CO₂ gas.

iii) The use of drying stores and core carriers, essential foundry sand and oil sand work is eliminated, together with the attendant bottle neck problems which arise when extra production is required from a limited store capacity.

iv) Good dimensional accuracy is obtained when moulds and cores are hardened in contact with a pattern or in core boxes. The sagging and distortion which is liable to occur with green or oil sand moulds and cores before and during storing is eliminated.

v) The process is capable of a high degree of mechanization for the mass production of moulds and cores.

vi) Raw material and capital investment costs are low.

vii) The process has proved to be extremely versatile. Its application ranges from small mass production of precision components to some of the largest engineering castings produced in the industry. It is suitable for cast iron, steel and non ferrous foundry.

viii) Mould wall movement resulting in an enlargement of the mould cavity while castings are solidifying is avoided. Feed metal requirement is low resulting in smaller riser and better yield.
ix) Process is free from toxic, poisonous organic chemicals compared with organic binder processes. Workers prefer it for this reason alone.

x) The process is pollution free. No gas or smoke is created during pouring and shake out. There is nothing in the sand to burn.

xi) These sands are nitrogen free.

2.7.1 Requirements for cleaning silicate bonded sand:

According to Morgan, (12) for efficient operation of the CO$_2$-silicate process the sand must be maintained at a fairly high quality, with low fines content, and high refractoriness. The process generates used sand which is contaminated by heated and dehydrated sodium silicate and sodium carbonate, forming a strongly adhering low melting point debris, together with a considerable amount of fines. Simple crushing and abrasion, followed by dust extraction yields a material having 1.2% of fines below 200 mesh, the fines still adhering to the sand grains.

Foundry grade sodium silicate (of 2:1 soda to silica ratio) contains 15-16% Na$_2$O. An addition of 4% of this to the sand mixture, (as normally used for bonding) will introduce 0.6% Na$_2$O in the sand. This is not lost or reduced during casting. Casting surface finish may be adversely affected if the total Na$_2$O content of the sand mixture exceeds 0.8%, especially for castings above 20 tons weight. For this reason removal of fines and soda ash by efficient dust extraction plant is essential. Unless at least 30% of the spent binder is removed at each re-cycling, the accumulation will cause deterioration in refractoriness and bonding properties of the sand mixture, leading to poor casting quality. Mineralogical changes also take place during heating of quartz grains in the presence of Na$_2$O resulting in the production of Silica fines and the disintegration of the quartz grains.
Higher percentages of soda may be tolerated when producing smaller castings, but much will depend upon the metal pouring temperature and surface coating applied to the mould. In general Na₂O content of the bonded sand mixture should not exceed 1%.

In practice the majority of foundries using a dry reclamation process for silicate-bonded sand have found it necessary to limit the quantity of recycled sand to 50% of the new mixture, for facing sands. Higher proportions than this can be used for backing sand mixtures by making a controlled water addition. However, wet scrubbing of the sand will give a cleaner sand, and can constitute up to 100% of the sand mixture for CO₂ sodium silicate process. Neither technique removes all the residual Na₂O and therefore the sand may be unsuitable for reuse with oil or resin binder process.

According to Richards (65) present reclamation techniques do not, therefore completely meet the basic requirements for a clean reusable sand mixture, after silicate bonding.

2.7.2 Classification of Sodium Silicate bonded sands: -

The sodium silicate bonded sands can be classified into (i) CO₂ gassed silicate bonds, (ii) self setting sands hardened with dicalcium silicate, and (iii) ester hardened silicates (66).

2.7.3 Difficulties in reuse and reuse level of sodium silicate bonded sands: -

According to Morgan (12) and Ryder (58), the presently available reclamation techniques for reclaiming CO-sodium silicate bonded sands do not satisfy the basic requirements. According to Morrogh (67) the residue to be removed from silicate bonded sands is a very unpleasant material, soluble sodium compounds can be discharged only
with difficulty as an effluent, ultra fine dried sodium silicate as a dust is difficult to dispose as it also contains very fine dust of quartz.

Pye (68) and Morgan (69) state that reuse levels only up to 50% of reclaimed sand can be achieved successfully using dry reclamation process for facing sands for CO₂ mixes. They claim that the use of 100% reclaimed sand is generally not possible. However, Crusishank company (70) has reported higher reuse levels of reclamation from dry reclamation process. Bidrate (71) reported that 100% reclaimed sand was effectively used for ingot production in a Spanish foundry. Srinagesh (72) reported the reusability of self setting sodium silicate bonded sand up to 70% in the moulding sand. Shahan (73) states that at Brea alloys with the installation of a new type of reclamation system and a small amount was water addition to the mix, reclaimed ester-sodium silicate bonded sand was reused up to 80%. They are also using 100% reclaimed sand in their oil mix, which has resulted in a reduction of the binder level needed.

2.7.4 CO₂-Sodium Silicate process in Foundries:

The CO₂-Silicate process (74) has been in the forefront of the revolutionary changes in mould and core making practices which have taken place in recent years throughout the foundry Industry. It has been proved as an exceptionally versatile process and has been enthusiastically adopted by iron foundries, steel foundries and non ferrous foundries, for applications ranging from heavy engineering castings to intricate mass production components.

Although the process has been in use for at least thirty years, important developments are still being made in the field of sand reclamation systems.
2.7.5 Commercial Sodium Silicate:

Sodium Silicate like clay is a generic term. Unlike clay, it is a man made material. There are several sodium silicates in the market, both in liquid and solid forms out of which foundries are interested only in a limited range. There are so many types of sodium silicates and the standard specifications are met by controlling, according to need, the alkali-silicate ratio, water content, colour, stability and viscosity. The percentage ratio of Na₂O: SiO₂ for liquid silicates (75) varies from 1:1.6 to 1:3.75 and the density from 1.318 to 1.872 g/cc.

Liquid sodium silicates can be considered as solutions of solid sodium silicate in water. Solid sodium silicates in turn are mixtures of sodium oxide [Na₂O] and silica [SiO₂]. Various ratios of Na₂O and SiO₂ can be mixed at will while manufacturing, to form a metastable compound sodium silicate. Sodium silicates used in foundries are mostly liquids and the typical ones are shown in the Table 2.2.

Table 2.2 Typical foundry grades of Sodium Silicate

<table>
<thead>
<tr>
<th>Ratio Silica/Soda</th>
<th>% SiO₂</th>
<th>% Na₂O</th>
<th>% Water</th>
<th>Baume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6</td>
<td>23.0</td>
<td>14.4</td>
<td>62.4</td>
<td>45.5</td>
</tr>
<tr>
<td>2.1</td>
<td>29.0</td>
<td>14.7</td>
<td>55.9</td>
<td>50.5</td>
</tr>
<tr>
<td>2.4</td>
<td>32.7</td>
<td>13.7</td>
<td>53.1</td>
<td>52</td>
</tr>
<tr>
<td>2.9</td>
<td>31.9</td>
<td>11.0</td>
<td>56.1</td>
<td>47</td>
</tr>
<tr>
<td>3.2</td>
<td>28.5</td>
<td>8.9</td>
<td>62</td>
<td>41</td>
</tr>
<tr>
<td>3.7</td>
<td>25.3</td>
<td>6.8</td>
<td>67.4</td>
<td>35</td>
</tr>
</tbody>
</table>
2.7.6 Soda-Silica ratio:-

Perhaps more important than any other term when specifying sodium silicate is the soda-silica ratio. It is very often understood as the ratio between the two components, SiO₂ and Na₂O in the liquid or solid sodium silicate. In strict chemical terms, this is not permissible since Si or Na does not exist in the form of their respective oxides, independent of the other elements involved, namely oxygen and hydrogen. The structural nature of the [loosely held] compound, liquid sodium silicate, formed of Si, Na, oxygen and hydrogen is still not clearly understood. Without a precise knowledge of the inter-atomic bonds, the composition is most conveniently indicated by referring to silicon and sodium as oxides and by expressing the ratio between them.

In addition to this, there is another simplification involved in the expression "soda to silicate ratio". What is meant by this is the ratio of the molecular SiO₂ to molecular Na₂O in the compound. Their respective molecular weights are 60 and 62. Because of the small difference in molecular weights of Na₂O and SiO₂, the ratio of the commercial sodium silicate is commonly expressed as the weight ratio.

When, for example, one mentions about a sodium silicate of SiO₂ : Na₂O ratio of 2, the right interpretation is, that for each molecular weight of Na₂O [62] there are two molecular weight of SiO₂ [120] in the mix. If it is taken to mean that each unit weight of Na₂O is associated with two unit weights of SiO₂, it would be but definitely in error. Hence it would be better to indicate whether molecular or weight ratio is meant.

Relatively small changes in the water content of commercial sodium silicate have an important effect as can be appreciated from the phase diagram of the SiO₂-Na₂O-H₂O system shown in Figure 2.10.
The diagram is best understood by considering the changes in composition and properties of 2:1 ratio [SiO₂:Na₂O] silicate solutions as the water content is either increased or decreased. From the diagram it can be seen that clearly that a small decrease in water content results in a large and rapid rise in viscosity.
Fig. 2. 10 COMPOSITIONAL DIAGRAM OF SODIUM SILICATES SHOWING PROPERTIES OF COMMERCIAL GRADES (after Vail: Soluble silicates)

Reclamation and reusability studies on CO₂-sodium silicate bonded sands for ferrous foundries.
2.7.7 Strength of Sodium silicate bonded sands:

The strength developed in the sand bonded with sodium silicate is, at best, vaguely understood. Inspite of several studies by several authors Srinagesh (76), Arnold Tipper (77), Nicholas (78) and Haley (79), the strength development is attributed to many reasons. The individual grains of sand covered with a thin coating of sodium silicate are bonded to one another during the process of mould or core making. The familiar strength measured as a gross property, is dependent on the strength of a large number of bonds within the mould and core mass, each grain being bonded directly to only a few grains. According to Srinagesh (76) the binding power of sodium silicate can be attributed to at least three apparently differing aspects of its nature:

1. It is very efficient wetting agent. When the surface of sand grains is covered with a coating of sodium silicate, particles of impurities, dirt and grease can be easily dislodged from the surface and will be floated off. Adhesion between such a cleaned surface and the binding medium is likely to be better than that with an unclean surface.

2. As a chemical, it is a metastable compound which can be made to decompose fairly easily. One of the products of such decomposition is monosilic acid, Si(OH)$_4$ is known to be unstable which polymerizes to polysilic acids. The polymers being macromolecules can adhere to the interfaces by multiple points of physical adsorption as well as by extending into the adjacent phase. They thereby form a bridge of multiple Vanderwaals strength as if they have diffused into the adjacent phases accomplishing a stitching action.

3. It is one of the best industrial adhesives. The contribution to binding strength due to adhesion is similar to other well known adhesives.
2.7.8 Supply of carbon di oxide:

At normal temperature and pressure carbon-di-oxide is a gas, but is more conveniently and economically supplied as either liquid or solid. For Sodium Silicate bonded sands, CO₂ gas should be used in the gas phase in order to effect the hardening of silicate bonded moulds and cores. According to John E Gotheridge, (80), it is advisable that cores and moulds should be slightly under gassed as some amount of increase in strength will be there due to storage. Taylor. D.A (81) states that the ideal method of gassing would be to supply gas to all parts of the mould and at a rate sufficient to replace that used in the reaction. If gas is supplied at a faster rate, than it fulfills no useful purpose and simply escapes to atmosphere. The CO₂ gas required to harden 1 kg of sodium silicate solution [SiO₂:Na₂O ratio of 2:1] has been calculated as 0.75-1.00 kg, although in practice the CO₂ gas consumption will depend upon the degree of hardening required, time used and the gassing practice employed. AFS Sand Division Core Test Committee (82) observes that the time of exposure to CO₂ has a greater effect on sand strength than the gas pressure.

2.7.9 Chemical reactions in CO₂ process:

Silica gel that binds together the sand particles nicely results from

\[
\text{Na}_2\text{O}-\text{SiO}_2 \cdot x\text{H}_2\text{O} + \text{CO}_2 \rightarrow \text{Na}_2\text{CO}_3 + \text{SiO}_2 \cdot x\text{H}_2\text{O}
\]

[Sodium Silicate] + [Carbon di oxide] \rightarrow [Sodium carbonate] + [Silica gel]

Silicic acid gel Si(OH)₄ proceeds the formation of silica gel. Condensed water from the polymerization of silicic acid gel is held in the capillaries of the silicic gel network which is fibrillar in structure. Silicic acid gel when condensed with water does not possess much strength. Strength can be achieved by removing the condensed water. Maximum strength is attained by the formation of dehydrated silica gel formation by a process known as synersis. The gel responsible for strong bonding strength between grains is visualized as a somewhat rigid but porous skeleton full of capillaries filled with water.
\[ \text{Na}_2\text{CO}_3 \rightarrow \text{Na}_2\text{O} + \text{CO}_2 \]

The alkali Na$_2$O in dilute solution can be neutralized by HCl addition.

\[ \text{Na}_2\text{O} + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{O} \]

2.7.10 Size of casting:

Waldemar Schumacher (83) states that by CO$_2$ process castings weighing up to 16 tons were produced.

2.7.11 Surface finish and Surface Roughness:

Moulds and cores made by the CO$_2$-process are normally given a protective coating to prevent the occurrence of metal penetration and the formation of "burn-on". According to Riley (84) for an addition of 0.5% soda the melting point of the silica sand is reduced from 1720°C to 1700°C. This is the usual amount of soda present in sands bonded with sodium silicate. The inferior surface finish of steel sections cast in CO$_2$ process sand is due to the reduction of the melting point of the silica sand by the alkali additions.

Surface Roughness

On any finished surface, imperfections are bound to be there and these take the form of a succession of hills and valleys which vary both in height and in spacing and result in a kind of texture which in appearance or feel is often characteristic of the machining process and its accompanying defects. The several kinds of departures are present on the surface and these are due to various causes. According to Gupta (85) roughness or texture in the form of a succession of minute irregularities is produced directly by the finishing process employed. In practice the complete roughness commonly represents a combination of irregularities of various kinds and magnitudes arising from several different causes and the individual effects of the separate contributing factors cannot always be readily distinguished. Thus for the complete study of the surface
roughness, it is essential that the measurement and analysis of all the component elements and an assessment of the effect of the resulting combined texture be made. All this being very difficult and tedious job, in practice all that is essential is that a practical method of assessment be followed, the result of which can be readily compared with a specified requirement of quality, preferably on the numerical basis. It is done by analysing the form of profile revealed by a plane section through the surface. The measurement of surface roughness poses a problem in three dimensional geometry, but for simplification purposes it is better to reduce it into two-dimensional geometry by confining individual measurement to the profiles of plane sections taken through the surface. The direction of measurement is usually perpendicular to the direction of the predominant surface markings or 'lay'.

When the irregularities are comparatively uniform in shape and size, then the distance between the successive peaks is described as pitch or dominant spacing. It may be appreciated here that the surface roughness is concerned both with the size and the shape of the irregularities e.g., in certain profile the height of departure may be wider or closer, or the spacing of the irregularities may be of various forms. Thus realising that both size and shape (i.e., height of irregularities, their spacing and form) are important for specifying surfacing roughness, it is not considered possible to express the complete roughness characteristic by means of any single number. The normal practice is, therefore, to specify $R_a$ value to define the quality or grade, and the manufacturing process which serves to produce the type of roughness.

The values of the surface roughness expected from various manufacturing processes are indicated in Table 2.3.
Table 2.3 Surface roughness of various manufacturing processes

<table>
<thead>
<tr>
<th>Manufacturing Process</th>
<th>Ra value in μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casting</td>
<td></td>
</tr>
<tr>
<td>Sand casting</td>
<td>5 to 50</td>
</tr>
<tr>
<td>Permanent mould casting</td>
<td>0.8 to 6.3</td>
</tr>
<tr>
<td>Die-casting</td>
<td>0.8 to 3.2</td>
</tr>
<tr>
<td>High pressure casting</td>
<td>0.32 to 2</td>
</tr>
<tr>
<td>Hot rolling</td>
<td>2.5 to 50</td>
</tr>
<tr>
<td>Forging</td>
<td>1.6 to 25</td>
</tr>
<tr>
<td>Extrusion</td>
<td>0.16 to 5</td>
</tr>
<tr>
<td>Flame cutting, sawing and chipping</td>
<td>6.3 to 100</td>
</tr>
<tr>
<td>Casting</td>
<td></td>
</tr>
<tr>
<td>Hot rolling</td>
<td>2.5 to 50</td>
</tr>
<tr>
<td>Forging</td>
<td>1.6 to 25</td>
</tr>
<tr>
<td>Extrusion</td>
<td>0.16 to 5</td>
</tr>
<tr>
<td>Flame cutting, sawing and chipping</td>
<td>6.3 to 100</td>
</tr>
<tr>
<td>Machining Operation</td>
<td></td>
</tr>
<tr>
<td>Radial cut-off sawing</td>
<td>1 to 6.3</td>
</tr>
<tr>
<td>Hand grinding</td>
<td>6.3 to 25</td>
</tr>
<tr>
<td>Disc grinding</td>
<td>1.6 to 25</td>
</tr>
<tr>
<td>Filing</td>
<td>0.25 to 25</td>
</tr>
<tr>
<td>Planning</td>
<td>1.6 to 50</td>
</tr>
<tr>
<td>Shaping</td>
<td>1.6 to 25</td>
</tr>
<tr>
<td>Drilling</td>
<td>1.6 to 20</td>
</tr>
<tr>
<td>Turning and milling</td>
<td>0.32 to 25</td>
</tr>
<tr>
<td>Boring</td>
<td>0.4 to 6.3</td>
</tr>
<tr>
<td>Reaming</td>
<td>0.4 to 3.2</td>
</tr>
<tr>
<td>Broaching</td>
<td>0.4 to 3.2</td>
</tr>
<tr>
<td>Hobbing</td>
<td>0.4 to 3.2</td>
</tr>
<tr>
<td>Grinding and Super Finishing Operation</td>
<td></td>
</tr>
<tr>
<td>Surface grinding</td>
<td>0.063 to 5</td>
</tr>
<tr>
<td>Cylindrical grinding</td>
<td>0.063 to 5</td>
</tr>
<tr>
<td>Honing</td>
<td>0.025 to 0.4</td>
</tr>
<tr>
<td>Lapping</td>
<td>0.012 to 0.16</td>
</tr>
<tr>
<td>Polishing</td>
<td>0.04 to 0.16</td>
</tr>
<tr>
<td>Burnishing</td>
<td>0.04 to 0.8</td>
</tr>
<tr>
<td>Super-finishing</td>
<td>0.16 to 0.32</td>
</tr>
</tbody>
</table>
2.8 PROPERTIES OF RECLAIMED SODIUM SILICATE BONDED SANDS

According to Paul Caray (86) the various factors affecting the quality of sand reclamation are binder content, sand to metal ratio, pouring temperature, type of sand additives and type of binder system. The experiments and tests to be carried out on reclaimed sand are (i) return sand temperature, (ii) screen analysis, (iii) loss on ignition, (v) pH value, (v) acid demand value, (vi) strength, (vii) Scratch hardness, (viii) magnetics and (ix) microscopic analysis.

According to Skubon (87) sodium silicate binders and alkyd oil isocyanate organic binders are more tolerant to clay contamination than most other chemical binders. He further stated that the successful performance of sand binders in the foundry Industry relies heavily on chemical control. According to Clifford (35) the AFS Clay content test on the reclaimed sand can be used for assessing the quality of sand. He also stated that the clay content of the reclaimed sand should be limited to 1%, and it could be used interchangeably with new sand to produce satisfactory casting. Mac Donald (20) states that the percentage of reclaimed sand used in the production of castings will depend on the soda content of the sand and on how it builds up. If the soda content is above a certain level, the reclaimed sand must be diluted to keep it below the danger point. The maximum tolerable soda level in these sands is between 0.5 and 0.75%. The exact amount will depend on a number of conditions including the base sand, casting section and possibly other additives that could alter the fusion point of the sand.

According to Lissel (63) it is customary to evaluate the scrubbing efficiency as the percentage of binder removed in the process. In the case of sodium silicate bonded sands the Na$_2$O content is normally used as an indicator of the binder content. Mac Donald (88)
also states that the tolerable Na content is between 0.5 to 0.75% and this can be controlled by the reclamation process or by dilution with new sand.

Morgan (12) states that higher percentage of soda can be tolerated in the case of silicate bonded sands when producing smaller castings, but much will depend upon the metal pouring temperature and surface coating applied to the mould. In general the Na$_2$O content of the bonded sand mixture should not exceed 1%.

The difficulties experienced in completely removing residues from reclaimed sand grains have inspired more detailed investigation of the nature of residues and their adherence to the sand grains. Examinations by optical microscopy can show the presence of any residue but may not give much information on its makeup. Morgan further states that it is possible to get better details by means of the scanning electron microscope.

According to Srinagesh (72) the quality of reclaimed sand in the case of self setting silicate bonded sand can be assessed in terms of AFS fineness number, coefficient of angularity and residual binder.

2.9 PROPERTIES OF REBONDED SODIUM SILICATE BONDED SAND:

Based on the joint program of investigation by the distillery companies and Baker perkins limited (89) they indicated that the casting finish was generally good with sodium silicate bonded reclaimed sand. According to Murton (90) the usual tests for mouldability and flowability did not indicate significant differences between sand mixtures made with new sand and those made with reclaimed sand. The weight of the AFS test specimen, permeability, green compressive strength, (which all appeared to relate to mouldability), and the dry compressive strength of the gassed specimens were the tests used in these investigations to compare the qualities of different specimens.
Nicholas (62) has determined the compression strength and bench life of reclaimed and rebonded sodium silicate bonded sands. According to Fosbinder (38), the scanning electron micrographs can show the nature of sand, the bonds, the residuals on the sand after cleaning and the effect of the residual clay on the bond. According to Hwang (91), the three major factors affecting the properties of reclaimed sand are (i) the residual binder on sand surface, (ii) fines generated during casting and reclamation processes and (iii) the metal or metal oxide accumulated on sand surface. While according to Srinagesh (72), the properties to be measured in the rebonded sodium silicate sand are the strength and binder build up. Caldeira (92) has reported that the properties of reclaimed sand can be easily assessed by bench life and pH. VICTOR.E.ZANG (93) stated that pH value can help foundrymen to produce better castings through better control of the colloidal binders in the moulding sand.

2.10 QUALITY OF CASTINGS FROM REBONDED SAND

Toeniskoetter (94) studied the performance of the reclamation process by examining the surface finish of the castings, casting peel and mould erosion resistance, by using the test castings. According to Morgan (95), to produce castings of consistent quality, it is important to know the high temperature properties of cores and moulds such as thermal expansion, spalling resistance and plastic deformation.

According to Tordoff (96), a variety of test castings, test parameters and methods of interpreting test results can be used to simulate the operating conditions found in the production environment. A step cone casting was specifically developed to evaluate a binder's propensity to produce gas defects. The penetration 2 x 2 test casting experiment can evaluate metal penetration tendencies better than the step cone casting test.
2.11 THE FUTURE OF SAND RECLAMATION:

Several authors have studied the future of sand reclamation (97-101). As to the future of sand reclamation - what new methods, processes, developments, or findings will influence this part of the metal casting industry is, at best, a guess. Ecological, energy and environmental requirements and pressures may radically alter the methods we use today in the future. Expanding and stricter ecological and environmental requirements will be responsible for an even greater trend, towards use of inorganic binders like Sodium silicate for mold and core production.

Changes in metal casting processes, changes in binder practice, changes in base molding and core making aggregates could definitely change the processes or methods that are now employed for sand reclamation. Ecological trends will dictate what type of binder systems will be used in the future and the sand reclamation system selected should be considered with this knowledge in mind.

Metal casting facilities in the future may find that federal, state or local ecological regulations and environmental restrictions, the kind of waste sand and other materials which can be safely disposed off in nature, will limit the land and which could possibly pollute or contaminate the soil or water sources by natural leaching action. Air pollution by harmful and noxious fumes as well as solid particulate matter has already received considerable attention in the past. To what extent, how fast, and at what price metal casting facilities will be required to participate in the universal program of "clean air and water" relative to waste sand disposal and reclamation is difficult to foresee. Manufacturers, engineers and designers of sand reclamation equipment as well as metal casting facilities should take into account the possible stringent restrictions in the disposal of the reclaiming unit's "waste product". 

RECLAMATION AND REUSABILITY STUDIES ON CO2 - SODIUM SILICATE BONDED SANDS FOR FERROUS FOUNDRIES.
It is possible that new methods or means for utilizing energy may be employed (ultrasonic, vibratory, microwave, magnetic, thermal forms energy) to remove the coatings present on the foundry's waste sand. Perhaps all, or some of these changes will take place in the future to alter the present day approach and methods to attain sand reclamation. Of this however, it is certain, that in future an increasing number of casting facilities will incorporate sand reclamation as an essential part of their plant and process, for reasons of economy and environmental regulations imposed by the society.

2.12 ECONOMICS OF SAND RECLAMATION:

Increasing costs and new methods of operation have resulted in the consideration of methods to reclaim sand in many foundries. According to Rohr (5) a detailed economic evaluation of existing sand handling practice in the foundry as well as reclaiming methods should be made before a decision can be made regarding the choice of sand reclamation method. Morgan (101) states that the economics of running a sand reclamation system are constantly changing due to the increasing cost of sand, additives, energy and transport. Assuming a reclamation plant to be wisely engineered, the simple fact to be kept in mind is that capital and operating costs often tend to be inversely proportional. In other words if long term economy is the aim, then system design can be arranged to minimize man power requirements. Morgan further states that superficially the reclamation options may be a little confusing but money can be saved by due consideration of every aspect of a proposed reclamation system. Initially the need was to prove the acceptability of reclaimed sand for reuse and to design and to prove the equipment to a point where simple and reliable operations can be ensured. Wootton (57) argues that the cost benefits of pursuing a reclamation policy are substantial while the slight technical complications which may arise
in reusing the reclaimed product are readily acceptable. Foundry sands bonded by silicates, furan, phenols, cement and alkyd iso-cyanates are all reclaimed for the purpose of avoiding high costs of purchasing new sand as well as for avoiding the cost of dumping the lumpy bonded sand.

Against these savings there are a number of cost additions such as

i) The cost of providing capital for the purchase of a reclamation plant.

ii) The cost of operating the reclamation plant.

iii) The cost of maintenance and repair of the plant.

To be viable in a specific instance, the reclamation process should show considerable savings in foundry operating costs and a "profit" after paying back the investment in plant and capital servicing, with a sensible allowance made for the effect of delay in recouping money laid out initially. CIATF (4) report of commission have determined the economic viability of reclaiming chemical bonded sand. The economic aspects of sand reclamation using mathematical model and computerized calculation have been studied by various authors (57,102, 103).