NOTES ON RAT-PROOF GRAIN STORES

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Rats are agile and graceful animals, skilful in burrowing, predominantly nocturnal. They find their way everywhere; no door is shut to them; they gnaw and burrow through almost all obstacles. They run and leap, they climb and swim. They are fond of animal food, but will eat almost anything: corn, fodder, all kinds of human food, eggs, young birds, small mammals. When pressed by hunger they display much boldness, their senses of smell and hearing are acute, and their intelligence is well developed.

They infest houses, stores and ships. They undermine walls, destroy woodwork, devour stores. Their skin is used for glove leather, their flesh is as good as a rabbit.

An East Indian species, the bandicoot, may measure over a foot in length.

CHAMBERS' ENCYCLOPEDIA.

INTRODUCTION

This paper consists of notes relating to the rat-proofing of buildings for the wholesale storage of grain. Much of the information is taken from various publications relating to the subject, a list of which is given at the end of the paper. No pretence whatever is made to original scientific knowledge and no claim is made to perfection in methods. Practically the whole of the information quoted in Sections I. and II. is based on a very valuable Memorandum on Plague Preventive Measures.
by F. Norman White, M.D., Major, late of the I.M.S., Officiating Sanitary Commissioner, with the Government of India. Permission to quote from this Memorandum has been kindly granted by Dr. White and all notes appearing in inverted commas are extracts from his Memorandum.

For convenience this paper is divided into four Sections. Section I. The Rat and the Flea; Section II. Plague and Anti-Plague measures; Section III. Rat-proofing of buildings; Section IV. Regulations relating to Rat-proof buildings.

SECTION I.

THE RAT AND THE FLEA.

"The common Indian house rat, *Mus rattus*, is a very domesticated animal and is rarely found far from human habitation. For shelter it seeks the darkest corners of the dwelling, especially if such offer facilities for burrowing and a convenient supply of food. Such dark corners are to be found in almost any Indian dwelling. The rat possesses remarkable powers of climbing, and the ordinary mud wall offers no difficulties. A hard, smooth vertical surface free from irregularities and projections is not easily surmounted. A water-pipe or a drain-pipe which can be grasped by the rat's legs and tail is easily climbed. A ledge, projecting horizontally nine inches or more from the wall, if quite smooth and hard on the under surface, presents an insurmountable obstacle. A rat may succeed in jumping on to a ledge 2½ feet high but not one 3 feet high." A rat may, however, scramble to a greater height up a very rough, uneven wall.

The common musk rat (an insectivore) is not so common nor so active as an ordinary rat and it is said that it does not harbour the plague-carrying flea.

"A rat becomes sexually mature at a little over two months; the most common number of young at a litter is five. The sexes closely
approximate each other in number. So prolific are rats that given sufficient food and shelter a pair of rats may become 80 pairs in the course of a year. In most parts of India the majority of *Mus musculus* burrow; burrowing does not appear to be essential provided shelter and freedom from molestation can be secured, a state of affairs that is everywhere found in Indian habitations."

An American Authority says that cases have occurred where a full-grown female littered 12 times in one year and that a rat can reproduce when 3 months old. The period of gestation is very short, it is said to be but 3 weeks.

"It was estimated that in Great Britain the proportion of rats to human beings was about equal and in the United States the rodent population was in excess of the human population. In the West Indies and cane-producing tropical countries the rat population is incredibly large. On one cane plantation in Porto Rico, where there were less than 500 people, 25,000 rats were killed in 6 months. At Panama at times migrations seem to occur and rats have been seen swimming in large numbers in the Canal and lock chambers. But rats do not commonly migrate from their homes.

The rat population of any town or village is very much larger in the neighbourhood of markets and grain stores than in other localities.

During the war the rat was almost ubiquitous. On the Western front numerous cases occurred where knapsacks hanging five or six feet above the floor had their contents destroyed in a night, the only possible means of access being from the floor. The rat would leap upwards, his progress being assisted by the roughness and inequalities of the wall. The trenches were infested with them; instances were known where the bones of fully clothed corpses were gnawed clean without the clothing being disturbed; much food was
eaten and destroyed; stores were damaged; clothing and equipment were rendered utterly unserviceable.

When food was plentiful dread of man was reduced to a minimum and rats became tame and slothful, sometimes being too lazy to scamper away from approaching footsteps. When food was scarce the starving rat became fearless and aggressive and it was under such conditions that leather belts, knapsacks and canvas coverings to food were ravenously attacked and immense damage done.

The loss due to the amount of injury done by rats is astounding even taken on a minimum basis. The annual upkeep per rodent in Great Britain, Denmark and France has been computed at approaching a farthing per day at a conservative estimate. All kinds of grain, eggs, poultry, wild birds, fruit, vegetables, flour, and all food products are attacked. An Iowa farmer reported that rats had destroyed 500 bushels of corn out of a total of 2,000 bushels. A Washington merchant stated that rats gnawed a hole in a tub containing 100 dozen eggs and within two weeks carried away 71 dozen without leaving either shell or stain.

Dr. White states:—"An adult rat consumes upwards of ½ oz. of grain each day. Let us take the case of an Indian town with a human population of a quarter of a million people. Such a town at a very low estimate will have a rat population amounting to half a million. Let us suppose that the rats of this town have a preference for a grain selling at ten seers for the rupee. The rat population of this town would consume grain each day to the value of Rs. 1,170 and at the same time do a vast amount of damage to human property of other kinds. (This sum is equivalent to Re. 1-11-0 per head of population per annum, an amount which if devoted to public health would insure freedom from plague and many other diseases as well.) Truly the inhabitants of this country in so gladly suffering the rat suffer in other ways than those of disease and death."
"Grain is the natural food of *Mus. rattus*, which is very largely vegetarian in its habit; in certain circumstances the house rat will devour "meat" or even the dead bodies of other rats, but uncooked grain is their chief article of diet. The variety of grain that is most attractive to rats differs in different parts of the country, but the rats of any locality are remarkably conservative. Usually the rat favours that variety of grain which forms the staple food of the human population among which it dwells."

"Very remarkable, too, is the facility with which the rat is able to identify dough made from the flour of the grain to which it is accustomed when several varieties are offered in exactly similar form. The addition of such substances as meat, fish, cheese, sugar, fats, condiments or salt, as a flavouring; to dough made of flour and water, does not in any way render the mixture more palatable or attractive to the rat. This statement is at variance with commonly accepted notions and many will find it difficult to credit that a rat has no very great partiality for cheese, for example. Nevertheless the above statement is based on the results of numerous controlled observations designed to determine this special point. It is not contended that rats won't eat such substances as those enumerated above; at times they will eat almost anything; nevertheless they exhibit universally a preference for grain, or flour made from grain in the form of a paste, in preference to all else, and they like it best unflavoured. Finally, rats *must have water* if their food be dry; sufficient water is obtainable from fresh, or wet, vegetables or grass."

**Rat Surveys**

In the United States rat surveys have been instituted. Rats are trapped, and large numbers are destroyed but certain specimens are secured for laboratory examination. It is thus possible by examination to know whether rodent plague is present, as it is believed plague always exists among rats for some time before the infection is transmitted to human beings.
A concerted and well sustained crusade against the rat similar to the "swat the fly" campaign is necessary as no individual or half-hearted effort will suffice. Energetic and sustained rat destruction campaigns will do much towards keeping the rat population at a low level.

Rats can be destroyed by trapping, by poisoning and by using their natural enemies cats and dogs, but in order to ensure any success all garbage and food refuse must be properly and promptly disposed of and all human food and stores carefully protected. Buildings, outhouses and yards must be built so as to prevent rat harbourage.

Trapping, if conducted with energy and with due regard to detail, is of considerable value as a plague preventive measure. Traps should be oiled to keep them free from rust but frequent washing of traps is not recommended, rats are not attracted by cleanliness which appears to make them suspicious. The best form of bait is dough made from the grain of the locality or fresh green vegetables such as cucumber.

The health officer of Colon reports the best results from mixing barium carbonate in proper proportions in dough and baking as a loaf of bread. Split cucumbers with the powder sprinkled inside also proved alluring. It was also attempted to catch rats by means of viscous, slow-drying varnish spread on baited metal plates hoping thereby to catch not only the rats, but their fleas as they left the dead body. This method proved more efficacious in catching mice as the rats were generally too wary to become entangled in the varnish. It was shown however that once a rat stepped upon the plate his death was certain.

"Most of the rat poisons on the market will kill rats if the rats can be induced to swallow sufficient but most of them are distasteful or repulsive to rats. All phosphorous poisons possess this disadvantage."
"The most satisfactory of all poisons and happily the cheapest, is barium carbonate" which is a heavy, white, tasteless, inodorous powder. As a rat poison it is certain in its action and safe to handle.

"When mixed with flour and water it in no way makes the mixture less palatable to rats who seem quite unable to detect its presence in spite of their singularly acute attributes of taste and smell." Mix one pound of powdered barium carbonate thoroughly in an enameled basin with three pounds of flour made from the grain which constitutes the staple food of the locality, add sufficient water to make a fairly firm paste. The resulting mass is sufficient for 2,400 baits each containing 3 grains of poison which are conveniently rolled into pill form. Clean hands and dishes are necessary. Place the baits on small pieces of paper in positions readily accessible to rats but not readily accessible to children and domestic animals. Fifteen grains of barium carbonate will kill a cat; 20 grains is fatal to chickens but a dog can withstand 140 grains. Careful records of the baits should be kept.

The Flea

Fleas are wingless insects probably related to flies, they possess saw-like biting jaws with other mouth appendages adapted for sucking, they possess long powerful bristly legs which enable the insect to take relatively gigantic leaps. It has been ascertained that the leap of the flea equals that of the locust, being two hundred times the flea's length. Ordinary fleas have assumed new terrors as it has been found that they are bearers of plague from rats to men, one flea at least being common to rats and men. (Chambers' Encyclopaedia.)

"The welfare of the rat-flea is so dependent on the plentiful supply of rats which they parasitize, and has so short a life apart from its proper host, especially if it be infected with plague, that 'anti-flea' measures receive no specific mention." Fleas alone, apart from the rat, are short-lived, especially if infective.
The best remedy in a house where fleas are suspected is absolute cleanliness, especially of the floors, where no organic dust should be allowed to gather.

The species of flea believed to be principally responsible for carrying plague is known as *Xenopsylla cheopis* in hot countries and *ceratophyllum fasciatus* in Europe. Another variety of flea is the *X. astia* but this variety is not credited with being a plague carrier. Fortunately *X. cheopis* is comparatively rare in Colombo save in certain limited localities and to this rarity is attributed the fact that plague outbreaks in Colombo are so limited. In India *X. cheopis* are numerous especially in plague-stricken districts. As hereinafter stated fleas are most numerous and active during damp and cold weather. They are said to be inactive when the temperature is over 80 degrees.

When a plague-infected rat dies the fleas immediately leave the body. They may then gain access to any domestic animal which may as a result become infected, but owing to the short life of the infected flea such occurrences are rare. Through the bite of an infected flea, bubonic plague, which is a kind of blood-poisoning with enlargement of the glands, may be contracted. One authority says:—The flea carries the plague bacilli in its stomach; these organisms grow and develop till the flea’s alimentary passage is entirely blocked. This does not, however, take away the flea’s appetite, but rather increases it, the creature becoming thirstier than before. The blood it sucks up, however, cannot pass into the stomach, and is forced back into the wound in the skin made by the flea’s mandibles and piercer; but this blood is now contaminated by plague bacilli, with the result that infection takes place. A more lucid description of this operation is given in Dr. Hirst’s paper on "The Transmission of Plague by Fleas." (Indian Journal of Medical Research, Vol. X., No. 3, January 1923.)
Amongst others some of Dr. Hirst's conclusions were:

(a) *Xenopsylla astia* and *Xenopsylla cheopis* are the rat fleas of Colombo. The former greatly predominate.

(b) *X. cheopis* was not found till after plague broke out. Its distribution on the rats of the city is irregular and is related to the distribution of rat and human plague.

(c) *X. astia* bites man reluctantly under tropical conditions.

(d) Experiments carried out with *X. astia* and *X. cheopis* under parallel conditions show that *X. cheopis* is a much more efficient vector (carrier) of plague than *X. astia*.

(e) Numerous attempts to transmit plague by means of *X. astia* from rat to rat, and from mouse to mouse, gave negative results during the plague season in Colombo.

(f) It seems probable that *X. cheopis* predominate on the rats of those parts of the East Indies liable to severe plague epidemics, and that *X. astia* is almost the sole rat flea of the regions relatively immune to plague.

The rats of Sea Street are particularly rich in *X. cheopis*.

**SECTION II.**

**Plague and Anti-plague Measures**

The rat is a greater pest than the fly because of its depredations and its possibilities for harm in the transmission and perpetuation of bubonic plague in a community. In the world-wide march of bubonic plague in no city should its advent be considered as improbable. Squirrels to the westward of the rocky mountains and the marmot in Asia are subject to the disease in a more or less chronic form but these animals, on account of their infrequent contact with man, are a menace not so much in transmitting the disease to man as they are
in being the source of a continued reintroduction of the disease among the neighbouring rat population. It is evident then, that the cry "No rats, no plague" is very expressive of fact.

Plague outbreaks generally occur during the damper and colder months of the year because rat-fleas are most numerous and most active during those periods. "Severe epidemics in the North of India have always been preceded by abnormally damp weather in the cold weather months, plague tends to disappear with the advent of hot dry weather."

"Plague as we know it in India is a disease of rats in which man and a few of the lower animals participate. The plague bacillus is spread from rat to rat, and from rat to man, and to certain other of the lower animals, by the bite of the rat flea. Were there no rats or were rats less "domesticated" or were the habits and customs of people in this country such that rats found it difficult to obtain food and shelter in human habitation, plague, as a human disease, would disappear from India."

An authority in the U.S.A. says that plague is primarily and essentially a disease of rats and it is conveyed from plague-infected rats through the agency of fleas.

In Colombo some months back it was found that a squirrel was a victim of plague. It was thought that the squirrel became infected by coming down to the ground thus allowing a flea from the body of a dead infected rat to hop on to it. Dr. Marshall Philip considered that there was extremely little likelihood of the infection spreading. The common squirrel of Colombo does not usually harbour fleas.

"Small outbreaks of this disease, which is extremely infectious, are occasionally experienced in India. These are, however, of Pneumonic plague"
infrequent occurrence and of small moment when compared with the incidence of *bubonic* plague."

"The *plague bacillus* is so short-lived outside the body of either the rat-flea, the rat; or man, that for practical purposes it need not be considered as possessing an independent existence."

**Antiplague measures**

Dr. White says that:—"Anti-plague measures may be grouped under four heads:—

*(a)* *Rat Elimination* or the prevention of rat infestation. This comprises such modifications in the habits, customs, and dwellings of a community as will result in a diminished rat infestation in the homes of the people and make the association between rats and men less intimate than at present.

*(b)* Measures designed to protect the rat population of any given town or village from plague infection. These entail a clear understanding of the manner in which plague infection is carried from place to place.

*(c)* Rat destruction designed, as is *(a)* to diminish the chances of infection, and to keep the rat population at so low a level that if plague be introduced the severity of the resulting epidemic will be appreciably diminished.

*(d)* If our efforts under these three heads fail to keep plague out it is left to try and render the human population immune to attacks of the disease by means of inoculation, or to remove the population at risk from close association with infected rats. The latter involves the evacuation of infected dwellings and provision of temporary accommodation outside the rat-infested, plague-infected area.

*(a)* *Rat Elimination* — In connection with the first of these measures, energetic and sustained rat destruction campaigns will do much towards keeping
the rat population at a low level. But "rat destruction campaigns are of only temporary benefit and it is necessary first to consider whether the houses, habits, and customs of people cannot be so modified as to render the association between the rat and human population less close than it is at present. As things are there is no limit to the amount of food and shelter that the average Indian house affords to the rat."

"All measures that lessen the amount of food and shelter for rats automatically effect a reduction in the number of rats. Protection of stores of food from the depredations of rats, and efficient scavenging are thus anti-plague measures of the first importance."

In Colombo the problem of rat elimination is somewhat complicated by the presence of an old system of untrapped drains leading into the harbour, dating back to the Dutch occupation of Ceylon. These afford an excellent shelter for the rats to live and breed in. From these drains the rats burrow into adjacent houses. In every city old disused drains should be completely removed and those in Colombo especially should receive attention.

Plague usually begins in the close vicinity of markets and grain stores because the rat population being very much larger in such localities plague when present spreads more quickly there than elsewhere. Thus grain exported from a plague-infected area goes from where plague is most severe to where rats are most numerous. "Not only so but grain and similar merchandise offer facilities for the transport of rats which baggage consisting of personal effects rarely affords. The movements of grain afford facilities for the dissemination of infection equalled by no other agency."

Most of the severe plague epidemics in Lucknow have originated from Ballygunj, the most important grain centre of that city.
Thus if grain stores could be kept rat-free a rapid diminution of plague would result. This object can be attained by building rat-proof stores.

Methods of grain transport demand the closest supervision. "The diminution of the facilities at present existing for rats to enter goods-wagons and carts, the breaking of bulk of consignments of grain, the erection of puccha platforms on which grain received loose can be bagged, these and similar measures all require attention in certain cases."

"Clothing and bedding from plague-infected houses may contain infected rat fleas, but merchandise is a more potent source of plague-infection."

"When articles from a plague-infected source are of such a nature as to render them likely to harbour fleas they can be rendered innocuous by exposure to the direct rays of the sun. The ground used for the purpose should be so chosen that the sun is able to shine on it for the whole of each day. It should be flat, devoid of grass, stones, or anything which might afford shelter to fleas. Preferably it should be covered with a smooth layer of fine sand three inches deep. The surface temperature of the sand should be at least 120°F. to ensure the destruction of all fleas. One-hour's exposure in such conditions is sufficient for the purposes of disinfection. Thick coats and razuis should be turned once or twice during the process. No articles should be placed within three feet of the edge of the sand."

(c) Rat destruction

The third measure (c) Rat destruction designed to diminish the chances of infection has already been referred to in Section I.

(d) Protection of a community

"Inoculation and evacuation of infected dwellings. When plague has obtained a foothold in a town, or when plague threatens, it will be necessary to press the claims of inoculation with plague vaccine. It is not
necessary to urge here the remarkable protection that inoculation affords to the individual; this is now well recognized. In the midst of an epidemic inoculation remains the most important of all plague measures.

Evacuation of infected dwellings should also be insisted on, but wholesale indiscriminate emigration from infected to uninfected places may be productive of much harm. "As long as things remain as they are, these two measures, inoculation and controlled evacuation, will be as necessary and as important as they are at present. It must be remembered, however, that plague in India is a disease of rats, first and last, and that these very valuable measures, inoculation and evacuation, designed to afford protection to the human population do not strike at the root of the evil."

SECTION III.

Rat-proofing of Buildings

The provision of 'rat-free' and rat-proof buildings for the storing of grain is of primary importance. As pointed out by Dr. White "The two terms 'rat-proof' and 'rat-free' as supplied to dwellings and store houses are by no means synonymous. Very little advantage is gained if the floors, walls and roof of buildings be so constructed as to make it impossible for rats to burrow therein, if such erections offer no lack of food and shelter to rats and if ingress and egress through doors and other apertures be not prevented by some special device. This word of warning is very necessary: in many parts of India one can see buildings that have been made 'rat-proof' harbouring, all the same, a very large number of rats."

These remarks must not be construed as meaning that properly constructed buildings having concrete floors, cemented walls and other excellent construction are not preferable in every way to buildings having earth or wooden floors, cabook or wattle and daub walls and other inferior materials but the provision
of excellent concrete floors and walls is not in itself sufficient to ensure freedom from rats. But even in most poorly-constructed buildings if food and shelter for the rat are rigorously removed rats will automatically decrease. As before stated protection of food stores and efficient scavenging are anti-plague measures of the first importance. Garbage and table refuse must be properly disposed of and rats must be prevented from gaining access to pantries, markets, stables and stores. Poorly constructed buildings however are dangerous inasmuch as rodents generally, even when abundant rubbish is available, prefer the more secure covert obtainable by burrowing beneath floors and under walling.

The Memorandum by Dr. White so freely quoted from, lays down excellent Rules or Conditions applicable and essential to the proper construction of grain stores:—

(a) Wherever possible the wholesale storage of grain should be effected in buildings apart from those in which retail trade is carried on.

(b) Wholesale grain stores should not be situated in close proximity to densely-crowded areas of a city.

(c) Wholesale grain stores should never be utilized for purposes of human habitation.

(d) Bearing in mind that water is essential for the life of the rat, no water accessible to rats, or fresh vegetables should be allowed in wholesale grain stores.

(e) As rats are unable to circumvent a smooth horizontal projection of nine inches, such a ledge surrounding a grain store on the top of a plinth 3 feet high is effective in prohibiting the ingress of rats. On the sides of the building in which the doors are situated this ledge can conveniently be enlarged into a platform 2 feet or 2 feet 6 inches
in width. Reinforced concrete is a suitable material for such ledges and platforms.

(f) The roof of the godown should overhang this platform and ledge to prevent the accumulation of rain water thereon.

(g) No steps or similar means of facilitating ingress should be allowed. In practice the inconvenience caused by the absence of such steps will be found inconsiderable. For unloading sacks of grain designed for such a store the bullock cart can be pushed close to the platform, which is also at a convenient height to facilitate the deposit thereon of sacks from a cooly's back.

(h) Rats, will, from time to time be introduced into such a store, but they will be compelled to leave in search of water, and should find their return extremely difficult.

As stated in para. (h) rats will occasionally obtain access even to such stores, the most usual method being inside the bags of grain. But stores built in compliance with these conditions will probably be as "rat-proof" as it is possible to make any building of this class which is designed for storage of grain.

Diagrams 1 and 2 illustrate designs for Rice Warehouses, large and small, which endeavour to comply with the conditions set forth above. The essential part of this design is of course the rat-proof dwarf wall and coping placed at doorways acting as a barrier and which follows the lines set forth in para. (c) of the above conditions.

These illustrate details to a larger scale and include doors, rat-proof barrier, ventilation boxes for cleaning, etc., at floor level.

The following notes describe these drawings in detail:
Notes on the Construction of Rat-proof Wholesale Grain Stores

1. The accompanying plans and details were prepared with the object of establishing a standard type of building for the wholesale storage of rice grain which would be suitable for Ceylon and as nearly as possible inaccessible to rats.

2. The designs embody certain features which were decided upon after careful study of actual conditions and reports collected from other countries, notably India and U.S.A.

3. It was evident from observation of the circumstances and conditions surrounding existing stores that any new measures could not be effective unless they were simple, convenient, self-acting and foolproof, while at the same time interfering as little as possible with the customs and methods of the coolies who handle the grain and the merchants who deal in it.

4. It was also understood that in spite of all precautions rats were occasionally introduced into the stores in the rice bags during the filling of the stores, modifications as outlined below were therefore adopted to minimise the consequences of the evil and to overcome it with the least delay and inconvenience.

5. Generally two types were necessary, one for smaller stores each compartment capable of storing 1,200 bags and the other for larger stores each compartment capable of storing 1,400 bags with space for re-bulking the grain. The bags which come from India have a different capacity to those in local use where the "bushel" standard of measurement is usual. Each type is capable of expansion with a minimum waste of material and labour to suit increasing requirements of space.

6. There is no limit to the increase in the number of compartments except the exigencies of the site and the congestion of transport vehicles. A length of 100 to 130 feet is pro-
bably a suitable maximum. It would generally be found advisable to repeat the block rather than unduly increase its length.

7. It will be noted that each type consists of a series of comparatively small completely separate rooms or store units with access from the outside through one door only, the object being:—

(a) To localise the area of possible attack and to minimise the quantity of rice accessible from any one door.

(b) To permit of only the store unit, (or units) actually in use having its door open, all other units being closed completely.

(c) To permit of intentional emptying of a whole compartment. Should rats or other vermin be detected in a unit the emptying of a compartment would be a small matter and the evil would be remedied at once. Should such intentional emptying be inconvenient the compartment is so small that it would be normally emptied in the course of a few days use. In either case there is the certain knowledge that the rats can be caught and that they cannot spread to other stores and that they cannot do unlimited damage.

(d) To facilitate the letting to merchants. A merchant may rent one or more units according to his requirements. Internal doors connecting units are not allowed as they would waste space and defeat the advantages of the "unit" system.

(e) To simplify expansion the addition of the required number of extra "units" can be effected with the absolute minimum of disarrangement of the existing structure and interference with the business being carried on.

8. It should be noted that the apparent extra expense of the division walls is partly compensated for by the fact that no roof trusses are required.
9. Verandahs are frequently used as offices by merchants and checkers and by the cooly labour at meal times. Such use is by no means desirable but the omission of verandahs would meet with great opposition. They are thus made wide, with cement concrete floors placed 6" above the ground and laid to falls so that moisture may be rapidly drained off.

10. Doors. These are of stout framed and braced construction and have edges protected with metal sheathing. The doors are hung folding upon W.I. strap hinges to angle iron frames. There is a 2" continuous rebate to all edges, which is sufficient to maintain a close impassable joint in spite of possible warping of the doors. The slightest warping of sliding doors provides an opening for rats and therefore folding doors fitting tightly into a rebate are preferable.

11. An Indian authority states that rats cannot climb a smooth face 3' 0" high. The doors have therefore been arranged with their sills at this level above the floor with the further precaution that the sill is a slab of reinforced concrete overhanging 9" on both sides. This constitutes the chief barrier against the entry of rats. It is effective at all times against rats except those actually carried in the bags. No steps are provided. The inconvenience of a door at such a height is more apparent than real as the only persons who have occasion to enter the store are coolies. Portage of rice bags is accomplished in relays and the slab door sill forms a most suitable platform for the transference of bags. This entails the double handling of bags but this slight inconvenience cannot be avoided.

12. Guard rails of old railway metals are provided to prevent carts backing on to the verandah and thus preserving the roof piers and walls, maintaining the verandah floor clean and safe while checking is facilitated and rats which may have been carried in the carts are prevented from scuttling into the store as would be the case if the carts backed directly on to the doors.
13. The provision of temporary steps or sloping ways of any kind should be strictly forbidden as these may be carelessly left while a door is open and unattended, thus defeating the whole scheme of protection.

14. It is quite certain that coolies, if unwatched, will place steps or planks sloping up from the floor or planks extending from the tail of a bullock cart across to the door sill so that bags of rice may be carried into the store without transference at the door. Such steps or planks would of course immediately provide a means of ingress for rats and the object of the wall barrier would be defeated.

The average total height of a man laden with a bag of rice is about 4' 4" to 4' 10" (see sketch of cooly) and the weight is so heavy that he is unable to stoop to pass through a low door. Therefore a door is shown having a cross "T" bar or cross head acting as a barrier placed 4' 4" to 4' 5" clear above the sill. This height is sufficient to prevent free passage of laden coolies but not low enough to interfere with the legitimate working of the store. Above the cross head a ventilating fanlight is placed fitted with closely woven wire mesh having holes not greater than \( \frac{1}{4} \)" every way.

Should it be desired at any time to use the store for any other purpose the cross bar and fanlight can be removed.

15. Light. No windows are provided, they are expensive and unnecessary and interfere with the stacking space. Ample light required while working is obtained through the open door and through glass tiles fixed in the roof.

16. Ventilation is effected by means of the fanlight over the door and two openings in the outside wall at floor level. The fanlight is protected by woven wire mesh and the floor openings are protected by castiron gratings with holes not exceeding \( \frac{1}{4} \)", these gratings are made to lift up so that when
necessary the entire unit can be washed out and drained dry. Additional ventilation is provided by means of a double roof at ridge level. This opening is carefully protected by woven wire mesh or perforated zinc sheeting nailed to battens. There are no other openings of any description. Walls are built up tightly to the tiles which are bedded in cement mortar at eaves, ridge, partition walls, etc.

17. Floors. The floors and damp-proof coursing are in the form of a continuous slab of concrete 4" thick provided with expansion joints, to obviate cracks which are filled in and pointed up with tar, cement and pitch, 3" clear of all walls and elsewhere if required.


19. Walls. Brickwork, cement plastered on the outside and inside to a height of 6 feet. Plain lime plaster above this limewhited.

20. Roof. Calicut tiles are shown but any other type of flat permanent covering may be employed. Stout purlins to span between partition walls are indicated no trusses being necessary. Eaves guttering and downpipes are not desirable and should be omitted. Eaves to project sufficiently for rain water to drip into the surface water drain.

21. White ants. The surface vegetation should be removed and traces of white ants investigated and any nests destroyed. The continuous concrete floor, the 3" solid concrete damp-course together with the general sound construction will render the structure white ant proof. It will be noted that the only timber below the roof is in the doors and these being hard wood and metal bound are not very liable to attack.

22. Water. Under no circumstances should water be left in or about the stores. Water is essential to rats and if water is not available this alone will be extremely helpful in minimising the rat menace.
23. A surface water drain of cement concrete must be constructed round the store to take away water from eaves and surface water. To be laid to ample falls and be kept perfectly clean.

These designs in their original form were prepared in the Head Office of the Public Works Department, Colombo. They are published in their amended form by the permission of the Director of Public Works. So long as the rat-proof barrier remains intact and provided no steps or planks are placed at the entrance to facilitate ingress it is reasonable to hope that this type of building will be proof against rats, except those which may be introduced inside and along with the bags of grain. But as pointed out such isolated rats can easily be caught when the unit is emptied. Indeed it would be difficult for the rat once inside a unit to make his escape.

"Relatively rat-free stores may be made of almost any material, provided the roof is water-tight, by raising the floor on uprights surmounted by rat-guards similar in design to those commonly employed on ships' cables. These uprights should be at least three feet high and would support the beams on which the floor rests. The floor might be made of wood. The space underneath the floor can be left open and kept free from weeds and rank growth with but little trouble."

In a country where good timber is cheap, rat-proof stores having wood plank sides and a corrugated iron roof can be constructed economically and efficiently on wood props. Wooden steps at doors might occasionally be useful to gain access but these should be made light and easily removable and care should be taken to see that they are immediately removed after use. It is essential that the props should be protected against leaping rats by a circular wood disc 18" diameter at least, fixed to each and every prop.

These discs are made in two pieces each of which is recessed to take half the width of the
prop and the pieces are joined by small battens. The props should be carried on concrete bases and the space under the floor and around the building for a distance of, say, 10 feet cleared and finished with rammed gravel.

Type, designs of rat-proof godowns on these lines have been received from the Secretary to the Commissioners for the Port of Rangoon. One design is entirely of wood and is a timber frame building with the floor placed about 5 feet to 6 feet above the ground on 6" × 6" props protected by discs as described above. The other design is of wood framing but mounted on a masonry base which consists of 18" outer walls 5 feet to 6 feet high, the floor being of concrete 6" thick and placed 4' 0" high above the ground. The space under the floor is filled with sand. An essential feature of this design is the weathered and throated corbelled coursing 6" thick which projects 6" from the wall and the top of which is 3' 6" above the ground. This provides an obstacle which a leaping rat would find it difficult to surmount.

In both designs access may be gained by a flight of wooden steps placed at the doors. A note on the drawing says: “Ladder to be drawn inside the godown before door is shut.” So long as this injunction is rigorously observed and acted on, this design of stores would appear to be perfectly satisfactory.

The designs are accompanied by most useful bye-laws which stipulate that nothing shall be stored or temporarily placed under the floors. Special stress is laid on the fact that if a rat obtaining access to the godown is deprived of water it will eventually die and therefore great care should be exercised in making the building rainproof and constructing the plinth and coursing that rain-water shall not lie on them. Great care should also be taken to remove by drainage all standing water from the vicinity. As timber-framed buildings are not economical in this country
and raised buildings are neither economical nor usual these bye-laws are not quoted here in full.

Diagram No. 5 shews how, by building an ordinary outer wall 5' 0" high around and guarding an existing store, that store can be made comparatively rat free.

The essential feature of this guard wall is its "loading platform" 3' 6" high placed opposite to existing doors. This platform is furnished with a projecting reinforced concrete capping which would act as an effective barrier against leaping rats. A guard rail is placed a short distance away to prevent carts from actually touching the wall or capping.

Other desirable features are the 2' 0" deep foundations to the guard wall under which a rat may not burrow and the cement concrete or macadam paving placed (if funds permit) covering the space between the guard wall and the building proposed to be protected.

If it is discovered that coolies are in the habit of placing planks up to the loading platform or from the tail of a bullock cart across to the platform so that bags may be carried into the store without transference at the platform, then it would be desirable to introduce a cross barrier at the height of 4' 4" above the platform as described in para. 14 in "Notes on Construction of Grain Stores." This could be effected by carrying the side pillars up higher and building a T iron between them at the required height.

It is not claimed that this method of protection is perfect. Particles of water might linger on the tops of the loading platforms but it is believed that the rat could not obtain access thereto. And again, the space between the guard wall and the building even if concreted and efficiently drained might perhaps not be absolutely free from water during the wettest seasons of the year.
It is quite possible that an ordinary corrugated iron fence would temporarily answer the same purpose as this guard wall if loading platforms were combined with it. Corrugated iron sheets which would be, say, 7 ft. long could be buried 2 ft. in the ground and project 5' 0" above the ground. Supporting uprights would then not be required.

Of course any boundary wall high enough and smooth enough to prevent rats scaling it and with foundations deep enough to prevent rats burrowing under it would be very helpful in excluding rats from any building or small site around which it was built. Such a wall must however be furnished with perfectly closely fitting doors, which, when shut, would absolutely exclude rats. These doors should not be allowed to remain open for any length of time and should always be finally closed before sundown.

Small shops for the sale of rice by retail to customers have been constructed in Colombo introducing at their entrances the dwarf wall protection with the projecting top to act as a barrier to rats as described in diagrams 1, 2 and 3. The lack of a full door reaching to the ground for ordinary access was however taken exception to by intending tenants who refused to accept a tenancy unless this obstacle to pedestrian traffic was removed. In consequence the dwarf wall was removed and an ordinary door was substituted. A sliding half door was provided in some cases in the place of the permanent dwarf wall. These substitutions satisfied the tenants but as a result the shops can no longer be considered as inaccessible to rats or in any sense rat-proof except in so far as their excellent constructive materials are concerned.

SECTION IV.

RULES FOR THE CONSTRUCTION OF RAT-PROOF WHOLESALE GRAIN STORES

Many rules have been studied but it is not considered necessary to produce repetitions of those which duplicate one another. The
following, which apply to Wholesale Stores and not to boutiques or small retail stores, are submitted as the minimum requirements for the purpose assuming that the best qualities of materials are used.

*Site* to be well away from densely populated areas, to be well above flood level, clear of all grass, vegetation and trees; to be levelled off and well drained. No other building or walling or trees to be allowed within 15 feet of a store. Direct access to the railway should be provided wherever possible. No grain store to be utilized for purposes of human habitation nor shall a human habitation be built within an enclosure wherein a grain store stands.

*Walls* to be constructed of concrete, brick or stone at least 9" thick laid-in cement mortar. No cabook or other material will be permitted.

*Foundations* to be carried down at least 2 feet below ground and to consist of concrete, brick or stone.

*Surface water drain of cement concrete* to be constructed around the Store to take away surface water and water from eaves, to be laid to ample falls and to discharge clear of site.

*Damp Course* to be of cement mortar 3/4" thick or of cement concrete 3" thick laid as a continuous slab.

*Floors* to be of cement concrete about 4" thick to be securely connected to walls laid at least 6" above the surrounding ground on a layer of hard dry rubble or filling.

*Cement rendering.* All walls to be rendered perfectly smooth in cement mortar 3/4" thick internally and externally to a height of 6 feet from the floor and to be limewhited. Above this height walls may be plastered in lime plaster.
Angles. All angles between floors and walls and all other internal and external angles of plastering to be rounded off.

Roof. All woodwork throughout to roof, doors, etc., to be once dipped and once painted in liquid fuel or Solignum. Roof coverings to consist of Calicut or flat tiles or other permanent material but no half-round tiles, thatch or wood coverings will be permitted. No enclosed spaces of any kind to be permitted in the roof. Walls to be carried up above wall plates right to the underside of tiles and the tiles to be bedded on to top of wall in cement mortar. Tiles to be bedded on to cross walls in a similar manner.

Eaves gutters. Guttering and downpipes are not desirable. Eaves to project sufficiently for rain water to drip into the surface water drain.

Windows are not advisable but where provided to be protected by a fixed wire or metal screen having apertures not larger than 1/4" either way. Glass tiles in the roof are preferable.

Doors. Sills of doors to be smooth cement concrete and to be fixed not less than 3 feet to the underside above floor and to be provided with projecting ledges 9" wide reinforced to act as a rat-proof barrier. Doors to be properly framed, to be hung folding to fit closely into a rebate, and to be bound at their edges with metal sheeting. A T iron cross bar to be fixed 4' 4" above the sill to obstruct the passage of laden coolies.

Ventilators to be provided at floor level and above doors and to be protected by wire screens or metal plates having apertures not larger than 1/2" either way. The plates to ventilators at floor level to be hinged to lift up to permit of the stores being washed out. A double roof ventilator may be formed at ridge but to be carefully protected by woven wire mesh or perforated zinc sheeting.
Steps. No steps or planks or similar means of facilitating ingress at doors will be allowed. The space near and around doors inside and outside to be kept clear of obstructions.

Ceilings. No ceilings or double floors or hollow walls or enclosed spaces will be permitted. No internal ledges to be formed on which a rat may rest.

Water. Under no circumstances will water be permitted in or near a store and no food or green vegetables allowed in a store.

Paving. The area in front of Store entrances for a distance of 8 feet to be paved with concrete, tar macadam or other impervious paving, preferably jointless, laid to fall away from the store. Paving is not necessary at the back and sides of a store. Where economy is essential hard rolled gravel may be substituted for the macadam.

Verandahs are not to be used for storage purposes.

Boundary walling. The site to be surrounded by a wall 5 feet to 6 feet high constructed of concrete, brick or stone with foundations at least 2 feet into the ground and surmounted with a projecting weathered concrete coping. The surface to be unbroken and to be rendered perfectly smooth in cement mortar. The entrance doors to be wood framed with metal protected edges and closely fitted at sides into an angle iron or rebated wood frame and at bottom against a stone or metal sill. Care to be taken that these gates are always finally closed before sundown and are not left open longer than is necessary for actual cart traffic.

REFERENCES

1. Memorandum on Plague Preventive Measures, by F. Norman White, M.D., Major, I.M.S.


5. Public Works Department, Ceylon. Notes on the Construction of Rat-proof Rice Stores for Outstations, etc.


Special thanks are due to Dr. F. Norman White, C.I.E., for permission to quote from his Memorandum. Dr. White is now on a Medical Mission to the Far East for the League of Nations, having retired from the I.M.S.

Thanks are also due to Dr. Marshall Philip, Medical Officer of Health, City of Colombo, and to Dr. L. Fabian Hirst, Bacteriologist, City of Colombo, for their valuable help and advice and to Dr. Hirst for permission to quote from his paper.
RICE WAREHOUSES FOR OUTSTATIONS. SHEET No.4

DETAIL OF DOOR

Scale 1:60

HANGING STILE

20 D W.C. Gabled roof sheeting. Ends bent &
cheek nailed sheeting to be carried at round door

MEETING STILES

ISOMETRIC PROJECTION OF C.I. VENTILATOR BOX

Scale 1:40

Public Works Department
Colombo. March 1919.
RICE WAREHOUSES

FOR

OUTSTATIONS

DRAWING SHewing METHOD OF RAT-PROOFING

ANY EXISTING GRAIN STORE

PUBLIC WORKS DEPARTMENT
COLORADO, MARCH 1859.
DISCUSSION

Mr. Woodeson in introducing his paper said: It is not necessary to go through the whole of this paper but in laying this Paper before the Association, I have to state that most of the information contained therein has been obtained from a valuable Memorandum on Plague Preventive Measures by Dr. Norman White. Dr. White is now on a Medical Mission to the Far East for the League of Nations and he will be passing through Colombo shortly. I was hoping that we should have had the honour of his presence here to-day.

The Rat. The breeding powers of the Rat are enormous. It is said that one pair of rats may become eighty pairs in the course of a year and that a rat can reproduce when three months old. It does immense damage to food and in the trenches during the War the rat was fearless and aggressive. It is strange to read that it has been proved that the rat does not necessarily prefer cheese as an article of diet, the preference appears to be for dough made from the grain which forms the food of the human population among whom the rat dwells.

The Flea. The Flea is a wingless insect possessing saw-like biting jaws. It is capable of jumping 200 times its own length.

Plague is carried to man by means of fleas from infected rats.

Dr. Hurst has found that Xenopsylla astia and Xenopsylla cheopis are the rat fleas of Colombo. X cheopis is a much more efficient plague carrier than X astia but fortunately in Colombo X astia predominates. The rats of Sea Street however are particularly rich in X cheopis. It is fortunate too that the Colombo squirrel does not usually harbour fleas.

Is devoted to discussing anti-plague measures, one of the chief of which is the rat-proofing of grain and food stores.
Section III. Outlines the conditions under which grain should be stored and describes how a store may be rat-proofed.

Special attention is drawn to the fact that a rat can jump on to a ledge 24 feet high but not one of 3 feet high. Advantage has been taken of this fact to interpose at doorways of the grain stores shown in the illustrations, a barrier wall 3' 6" high with a projecting concrete top or ledge to which a rat cannot gain access. This is the essential part of the scheme for excluding the rat.

The stores have been planned in small units sufficient to take 1,200 to 1,400 bags with the object of ensuring that a unit shall be emptied frequently in the usual way of business.

Undoubtedly an occasional rat will gain access to a unit and when this occurs the rat can be speedily caught. Moreover the rat can neither escape nor proceed to adjacent stores.

Thus there are two safeguards (a) the wall barrier and (b) the frequent emptying and cleansing of each unit.

In villages or on Estates small stores may be desired, but the minimum of compartments to be constructed for one store should be three. This is necessary to permit of, and to ensure, the occasional emptying and cleaning out of each compartment perhaps in rotation. Such emptying is an essential feature of the scheme.

Section IV. Gives rules to be followed in constructing Rat-proof grain stores. Emphasis is laid on the removal of all water from the vicinity of a grain store. Water is absolutely necessary to the life of a rat and if deprived of water a rat will surely die.

Mr. Prowse: I have carefully read this paper and have listened to the able explanation of the diagrams given by Mr. Woodeson. The two outstanding non-technical facts which appear to me in the paper are the propensities of rats and fleas. I am very glad that
the human population does not increase in the same ratio as rat population. Otherwise we should probably find that there would be more unemployment in the world than there is at the present day. (Laughter). As to the flea it would be very useful indeed I have no doubt to have the advantages in their methods of progression, in as much as one could skip over obstacles getting to one's destination even in these days of motor cars in a much quicker period. (Laughter). In regard to the paper it has been very carefully prepared. As a compilation as well as a document, to my mind, it is so valuable that I consider the paper such as it is with the attached drawings should be printed in pamphlet form and sent to all who in any way have control over, or are interested in the erection of Grain Stores in towns, villages or in estates throughout the Island. (Applause). The language used in the paper, and the drawings which illustrate it, are of such simplicity as to be readily understood by anyone who desires to obtain information which is therein available and which if made use of in any degree, must, as a result in the same degree lessen the dissemination of plague infection by means of rat fleas. By the compilation of this paper if it is made available to the Public, the author will have rendered a great service; not only to those resident in this Colony, but to all in general, in showing how by a simple method the spread of plague from rat fleas could, to a very large extent be circumvented. It now remains for this paper to be placed in the hands of all who could carry into effect these simple methods. The printing and the distribution of this document, is to my mind worthy of consideration and approval of Government in the interests of the people of the Colony (loud applause).

The President: I hope some other member or members will have some remarks to make on this paper.

Mr. G. S. Jacobs: May I ask if any cases have been reported in Ceylon of rats attacking and nibbling through lead water pipes?
During my stay in Bermuda a number of cases were brought to my notice of lead piping to flushing cisterns being nibbled right through by rats, presumably in order to obtain water, which during the dry season was very scarce in Bermuda.

Mr. Courcy Carson: I presume the interior of the wall is cement plastered, because rats will run up the ordinary plastered wall.

Mr. A. P. Nathanielsz: I happened to be in Galle on the outbreak of plague. It is rather strange that just a couple of months before the occurrence I was visiting some of the slums where I happened to meet the medical officer. I drew his attention to the insanitary conditions and said that I believed plague would very soon break out in Galle. My reason for saying so was, that while making investigations for a drainage scheme I happened to notice in many of those old buildings, drains running right under them very rarely cleaned out. The first case of plague that was noticed in Galle was within a hundred yards of this very spot which shows that the dark chamber-like drains under houses in Galle really harboured the rats which caused the plague. The trouble in Galle I understand was that when rats were trapped they were liberated. Galle is a Buddhist town and the people were averse to the rats being killed. I want to know, Sir, whether it would not be advisable in out-of-the-way places to encourage ratsnakes. (Laughter). Ratsnakes I believe do no harm. They certainly kill rats. It would be well to enquire whether there would be any danger in encouraging ratsnakes about villages and places where rats are numerous. Another point I noticed in Galle was that about Rs. 4,000 or more was spent in putting up a 6 ft. high rat-proof fence. The author says that a height of three feet would have been ample. In the future we shall be able with the information before us in this paper to save money.

The Hon. Mr. T. H. Chapman: The burrowing of rats is the question one has to consider.
It is exactly the principle that Mr. Nathanielz has spoken about. The rat-proof fence in Galle as far as the order has been given was 3' 6" above and 2' 6" let into the ground, of corrugated sheets. There is no doubt that rats do burrow and burrow fairly deeply in certain cases. I think in regard to rat snakes we may run the danger of creating a bigger nuisance than the rat. (Laughter). At the same time there is no doubt that the publication of this paper far and wide will do a great deal in encouraging people who have to store grain, to build suitable rat-proof houses and the people of the Southern Province who may not be pleased to kill rats will certainly be able to take steps to prevent them from entering their grain stores. The adoption of such methods as Mr. Woodeson has suggested will prevent them. (Applause).

Mr. C. H. Kilmister: Mr. President, as most of the members are aware the Municipality has already constructed rat-proof boutiques in Gas Works Street. The Members visiting Katanena Market on Friday morning will have the opportunity of seeing more rat-proof rice boutiques. In connection with them, and lest you comment upon the construction at the time, I would like to point out that the original design of these rice boutiques and those in Gas Works Street was very similar to the one that is illustrated in Mr. Woodeson's paper, with a guard wall, but unfortunately owing to local prejudice we were obliged to pull that wall down and make a sliding door. I only hope that the suggestion pointed out by Mr. Woodeson in his paper will be carried out, because there is no doubt that such a wall is essential in all rice boutiques if they are to be properly rat-proof. I assure you it was not the fault of the Municipal Engineers that these walls were not put in the Municipal Rice Boutiques. They had to be removed as I said, on account of the great opposition to them. (Applause).

Mr. Woodeson replying: I should like to answer the last question first. With reference to Mr. Kilmister's remarks, it is sometimes a
pity a paper is taken entirely as read because certain points in the paper are thus not brought out. On page 25 there is a paragraph relating to the model boutiques that Mr. Kilnister refers to. With reference to Mr. Chapman's remarks as to burrowing; in the detail plans burrowing has been allowed for or guarded against by the provision of metal paving, concrete flooring, foundations about 2 feet 6 inches deep. This also applies to the guard walling. Mr. Nathanielz, suggested that 6 feet was unnecessarily high for the fence. It is not suggested that the rat will not jump five feet if assisted by a rough surface but it would be difficult to jump five feet up a smooth surface and certainly it could not in addition surmount a projecting ledge which might be placed on the top of the fence. If a projecting ledge is placed at the top of a lower fence such lower fence would answer the purpose. With regard to the question as to the finish of the surface of wall it should be specially smoothly rendered in cement. This applies to all the faces of walls up which a rat may attempt to climb. This point is noted in page 3. Last, with regard to the question by Mr. Jacobs it has been noted that American papers have recorded that rats eat into lead pipes.

The President: Gentlemen, I am sure we are all very much indebted to Mr. Woodeson for the very valuable paper which he has contributed. I agree entirely with what Mr. Prouse and the Director have suggested, that this paper should be published and circulated for information. If the discussions on other papers are taken in like manner, I think these meetings are certainly going to be successful. I now have pleasure in calling on Mr. Bamford to introduce his paper on 'Cyclonic Movements in Ceylon.'