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RUBBER BINDERS FOR FOUNDRY CORES

Introduction.

The removal of cores from castings is an expensive, laborious and dusty task, often requiring the use of a pneumatic chisel or other tools. Cracked castings, due to hard cores which do not crush as the metal solidifies, are also a source of loss especially in aluminum foundries. Core blows, due to low permeability of the core, are still another source of loss. Green sand cores are used to avoid these troubles where it is feasible to do so, but the weakness of green sand cores prevents their use in many cases where the foundryman would use them if he could.

The Bureau of Standards has discovered a class of core binders whose outstanding advantages are:

1. The cores crush readily, falling to loose sand of their own accord so that the core sand may be poured from the casting instead of having to be dug out.
2. The cores have greater strength than a green sand core and extend the range of jobs to which a readily crushed core may be applied.
3. The cores are not oven-baked, they are merely air-dried.
4. The cores are of high permeability and remarkable freedom from blowing.

Since no other core binders have such a set of properties it is natural that the choice of the sand and the core-making practice will vary from that for other core binders and that best results should not be expected if the new binders are substituted for others without first making sure that the core sand is of the proper type to give the benefits of the new binders. At present this has to be done by experiment.

The new binders consist of rubber, of balata (a material similar to rubber in many of its properties) or of a special commercial type of rubber cement, each dissolved in a suitable solvent such as gasoline for plain rubber and benzol for balata and the special cement.

Fire hazards.

Since these solvents are flammable it is obvious that their use constitutes a fire hazard, and equally obvious that the preventive methods used in other manufacturing processes using such solvents can and should be applied. Anyone who is not willing to enforce such measures should not attempt to secure the benefits of the new binders.

It is probable that by suitable choice of solvents the fire hazard can be greatly reduced, but research along those lines need not be undertaken until more information is available on the applicability and utility of the binders.

Sand.

Inasmuch as the chief reason for using the new binders is to make the knocking-out of cores easy, it would be foolish to use a sand which, irrespective of the binder used, will bake hard by the heat of the casting and require digging-out anyway. Hence the core sands for these binders should be free from, or very low in, clay content.

Since most of the binders are aimed to extend the range of green-sand core work rather than to replace hard dry sand cores, it is advisable to select a sand that will lend itself to the production of a sufficiently strong core, rather than to handicap the binder by using an unsuitable sand and thus to require more binder. As a matter of fact, rubber is rubber whether is is in a rubber sole or a core, and the use of too much rubber will give a core that is too flexible without greatly increasing its strength. The purpose of the rubber is to hold the sand grains in contact with each other and maintain their bearing on each other. It does not, in itself, dry to a strong, stiff substance, but to a flexible one.

Fineness tests of sands which have been found suitable for use with these binders are given in Table 1.

Moisture content of sand.

Since the rubber binders are not baked in an oven but are merely air-dried, the sand used should be dry. If not practically free from moisture the sand should be dried before using. The rubber bond will not adhere well to damp sand and moisture in the core might tend toward blowing especially on a sand of low permeability. However, free-flowing air-dried sand is ordinarily suitable without drying by the application of heat.

Table 1.

Fineness Tests of Core Sands

Sieve #	Core Sand #1 % retained on sieve	Open Hearth Sand #2 % retained on sieve	Rattler Sand #3 % retained on sieve
6	0	0	0
12	.2	0	0
20	1.5	.8	0
40	19.7	8.6	1.6
70	51.8	47.0	13.7
100	14.2	30.8	18.0
140	6.0	7.1	13.7
200	3.0	1.4	13.0
270	1.1	.3	9.0
Pan	1.6	.8	31.0
Grain	99.1	96.8	100.0
Clay	0.9	3.2	--
Permeability with rubber binder, 7% by volume	444	202	32
Compressive strength with rubber binder as above and dried 24 hrs, lbs/sq.in.	10.8	12.2 (8.1 in another exp riment with a different lot of rubber cement)	6.2

The plain rubber binder.

Choice of rubber

In order to distribute the rubber over the sand grains it must be dissolved in a solvent. (There are possibilities in the use of latex, i.e., "rubber milk" but so far this has not been found as satisfactory as dissolved rubber).

Vulcanized rubber is not soluble so the plain rubber binder is not an outlet for old automobile tires or tubes. The rubber must be raw, unvulcanized rubber. Crude rubber as received is not satisfactorily soluble until it has been "milled" or "masticated", i.e., kneaded and worked between rolls or in other suitable apparatus. The trade designation for a suitable rubber is milled smoked sheet. It may be obtained from rubber goods manufacturers in the milled condition. Rubber is somewhat variable and the behavior of different lots may vary somewhat. The rubber should go into solution in gasoline as described below, forming a cement much like that used for tire repairs. Commercial rubber cement may or may not be suitable. Makers of rubber cement who understand the use to which the material is to be put should have little difficulty in preparing a suitable binder.

Preparation of the rubber-gasoline solution.

The gasoline used should be of a quality, so that only traces of a kerosene-like non-volatile residue are present. The type of gasoline commercially known as "aviation gasoline" is satisfactory.

The rubber is cut into small pieces so as to present a large surface to the solvent. A good ratio of rubber to solvent is one pound of rubber to two gallons of gasoline, i.e., approximately 7% by weight. Any suitable method of mixing can be used. Experimentally a simple way is to put about 1/4 lb. rubber and about 2 quarts gasoline in a large glass fruit jar, tightly close the jar and mount it on a rotator (such as was formerly used in the A.F.A. fineness test method for washing sand with caustic soda for the separation of clay bond before it was supplanted by the stirrer method). The best results are obtained if the jar is not entirely filled so that the air space allows greater motion of the contents.

The up-ending of the container as it is rotated mixes the rubber and gasoline, and when the solution is complete (mixing over night will usually give complete solution) the binder is ready for use. The solution must be complete, with no clots of undissolved rubber. It should, of course, be kept in a tightly closed container till it is to be used to prevent rapid evaporation of the solvent.

Mixing the sand and the binder.

The binder is mixed with the dry core sand in any suitable type of muller or mixer, or, experimentally, by hand-rubbing. For the sands mentioned in Table I about 3-1/2 parts by volume of binder to 40 parts by volume of sand (or 92 parts sand to 8 parts binder) is suitable. (Since the binder contains about 7%

rubber by weight this corresponds to much smaller percentage of actual rubber). The mixing operation must be carried out with due regard to the flammability of the gasoline. If the gasoline evaporates too fast, the binder can be diluted with more gasoline before using. Sand that is partly dried out can be retempered by adding gasoline but some time must be allowed for the mass to become of uniform temper.

When the sand and binder are properly mixed, the mixture does not have the "stickiness" of the cement, but will rub off the hands readily and will not stick to the core boxes. Tempered sand should be kept in closed containers to prevent too rapid loss of gasoline. The core bench should have good ventilation, with proper precautions against any danger of fire or explosion from the gasoline vapor drawn off. If large scale operation is carried on, recovery of gasoline from the ventilating system might be advantageous.

After the core is rammed, just as any other core is rammed, it has a strength rather higher than that of ordinary rammed molding sand, and much higher than that of an oil sand core as it comes from the core box. Nevertheless the cores need rodding much as a green sand core would. Since the rods or wires come out readily without being distorted in digging out the core, bent wires can be reused over and over again.

<u>Drying the molded core.</u>

The next operation is drying the core. Small cores up to say 1-1/2" diameter, especially if a sand of high permeability is used, will loose gasoline so rapidly that they can be placed in the mold at once, without waiting for drying out, a matter of considerable convenience in a rush order for a cored casting. While a small amount of gasoline doubtless remains, it has given no trouble.

Larger cores should be allowed to dry at room temperature and, if the recovery of the gasoline is desired this should obviously be done in a closed chamber through which a gentle current of air is drawn, and the solvent recovered by usual solvent recovery methods, with proper precautions against fire. On a small scale, or for experimental purposes where it is not desired to recover the gasoline, simple air drying, away from flame or sparks, will serve. Slight warming as with a steam coil will hasten the evaporation of the gasoline.

The rate at which the compressive strength develops in cores 2" high by 2" diameter (standard permeability specimen) is shown in Table 2.

Hence the cores may be used within a short time, or may be used after drying over night, or for a longer period. The moisture resistance of the cores, i.e., their ability to be used after long storage, appears to be very good but has not yet been quantitatively studied.

The rubber bonded cores are <u>not</u> to be baked as other cores are baked.

Table 2.

Rate of Increase of Compressive Strength on Air-Drying.

Mixture: 40 parts #2 sand of Table 1; 3-1/2 parts plain rubber cement.

(92% sand by volume, 8% binder by volume).

Cores air-dried at summer room temperature, no air current used.

Time after molding	Compressive strength* lbs/sq.in.
At once	2.5
1/2 hr.	5.0
1 hr.	5.7
1 1/2 hrs.	7.0
2 hrs.	7.5
2 1/2 hrs.	8.0
3 hrs.	8.8
3 1/2 hrs.	8.75
4 hrs.	9.0
4 1/2 hrs.	8.8
5 hrs.	9.0
24 hrs.	8.1

* Standard A.F.A. method.

Thus it will be noted that over half the strength is developed in the first half hour and practically the full strength in 2 1/2 to 3 hours.

Venting the cores.

With any size or shape of these cores yet tried at the Bureau, in castings of any metal, no venting has been required, The permeability is high and the core-prints give sufficient vent.

Placing the cores.

It must be remembered that the plain rubber cores are not as strong as baked sand cores. They must be rodded and placed much as green sand cores, but are enough stronger so that there is far less danger of breakage than with a green sand core.

Casting.

Casting of the metal differs in no way from the practice when other cores are used. It would be expected that an objectionable odor of burnt rubber would be noted, but with ordinary shop ventilation this is scarcely noticeable.

Shaking out.

If a core sand sufficiently low in clay has been chosen so that the heat of the casting has not baked the core due to the clay bond alone, the core will, of its own accord, or on slight tapping, fall into loose sand and will pour cleanly from the casting, without any sign of "burning-on" of the sand. The plain rubber bonded core sand from a lead casting, if the sand is not so coarse that the lead grips the outer grains too much, will break up and pour freely while baked cores will not. The same free-flowing behavior of the core is met in castings of tin, zinc, brass, bronze, phosphor-bronze, aluminum, cast iron, and even steel. Although the core disentegrates very readily, it nevertheless holds its form till the metal is frozen and gives a casting true to the core. Core sand which is not refractory enough for a steel casting, when used with rubber binder has freed itself from steel without any "burning-on" whatsoever. There is probably a limit to the size of the core and the mass of metal cast around it in which these binders will give a casting true to the core, but as the Bureau's work has so far been confined to relatively small castings it is not yet known just what this limit may be.

A phosphor bronze bushing 3 1/4" outside diameter 3/4" inside diameter 7" long cast around a rubber bonded core gave excellent results.

Aluminum copper alloy with 8% copper (No. 12 alloy) cast as a thin-walled box with sharp edges and corners, which would have been liable to crack when cast around most cores, did not crack with the rubber-bonded core.

Re-Use of core sand.

The burnt sand from a rubber bonded core may be reused. One possible draw-back may be the contamination of the molding sand by the core sand since the core sand falls out of the core so readily that it may be difficult, in some castings, to prevent its mixing with the molding sand.

Plain rubber plus "stiffeners" or "anti-softeners."

Zimmerman and Cooper[1] point out that certain chemicals act

(1) Zimmerman, E.C., and Cooper, L.V., Softeners and anti-softeners, Ind. Eng. Chem. 20, 1928, p. 812.

as "stiffeners" of uncured rubber. Among those mentioned are benzidine and para-amidophenol. A quarter of a percent of the former or a half a percent of the latter on the weight of the rubber is said to stiffen uncured rubber about 40%. Since the rubber in the core is uncured, this offers a means of getting a somewhat stronger core.

Benzidine was dissolved in ether and added to the plain rubber cement in proportion to give 1/4% on the basis of the rubber present. The strength of the core using #2 sand (Table 1) is shown in Table 3, the data of Table 2 being also repeated for comparison.

Table 3.

Rate of increase of compressive strength of plain rubber cement cores with and without "stiffeners."

All cores made with #2 sand (Table 1) in ratio of 40 parts sand 3 1/2 binder by volume (92:8).

Time air drying after molding	Compressive strength, lbs./sq.in. Plain cement	Plain cement plus benzidine
At once	2.5	2.7
1/2 hr.	5.0	5.2
1	5.7	6.65
1 1/2	7.0	8.2
2	7.5	9.1
2 1/2	8.0	10.3
3	8.8	10.5
3 1/2	8.75	11.4
4	9.0	12.5
4 1/2	8.8	12.7
5	9.0	13.7
24	8.1	15.2

Fairly rapid increase in strength is shown up to 3 hours without benzidine and up to 5 hours with it, and the maximum strength, is quite materially improved by the "stiffener."

This is the only set of experiments that has been made on "stiffeners" so far but the matter is obviously worth carrying farther as it offers a means of increasing the strength of the core or of reducing the amount of binder.

Vulcanization.

While there are possibilities in the idea of adding powdered sulphur, sulphur in carbon bisulphide or the use of sulphur chloride, and hardening the rubber bonded core by heating to bring about vulcanization, the difficulties in the way of producing a core finally bonded by hard rubber are many, and these possibilities are not to be realized at present,

Balata core-binder.

Rubber is not the only substance of the rubber group that can be used ascore-binder. Guttapercha and balata, the latter being usually more readily obtainable in the market, may be similarly used. These materials, which are used in the manufacture of belting, golf balls and insulation for submarine cables, differ from rubber in that they contain a high content of resins, are not vulcanized, and they have the peculiar property, not possessed by rubber, of softening at temperatures in the neighborhood of 100°F and hardening again on cooling.

This offers a means of restricting the fire hazard to the single operation of tempering the sand, and simplifies the problem of solvent recovery.

Balata, dissolved in benzol in about the same proportions and by the same method as is described above for rubber, may be mixed with core sand, selected with proper reference to sieve analysis, and when the binder is thoroughly distributed over the sand, the solvent may be evaporated. The unrammed sand does not stick together and may be stored like ordinary sand. By thus treating the sand in a mixing room so arranged as to be free from fire hazard, no solvent is brought to the core bench and there is no further fire hazard.

When it is desired to mold the core, the balata-covered sand is heated by steam coils or on a hot plate, with stirring to secure uniform heating. As the temperature rises to that at which the balata becomes plastic the sand begins to matt together slightly and a heap of it will "crawl". The plasticity is retained to so low a temperature that hand ramming can be done without discomfort. The warm sand rams just like the rubber bonded sand. After the core is rammed it is allowed to cool, and as soon as it is cold, the core is ready for use. Thus, instead of core-baking, core-cooling is required.

The balata cores have, for a given amount of bond, about the same strength and properties as the plain rubber cores previously described, and disintegrate equally well after the metal freezes. Notwithstanding the fact that the binder gets plastic on heating, no trouble has been met in the cores failing to hold their shape against the metal and the castings come true to the cores.

The present price of balata is about twice that of milled smoked rubber. The difference in price may perhaps be made up by the greater simplicity of solvent recovery and the reduced fire hazard. The prices of benzol and aviation gasoline ordinarily do not differ greatly.

Special "thermoprene" cement.

General

A special cement has been placed on the market recently, one of its chief uses being to fasten sheets of rubber to metal surfaces, as in lining tank cars with rubber. This cement is a proprietary article sold under rather stringent restriction as to the applications that may be made of a given purchase. It is a specialized, and so far, a high-priced material. The material is said to be a rubber isomer (that is, to have a similar ultimate chemical composition to rubber, but a different molecular arrangement) obtained by heating rubber with para-phenolsulphonic acid or sulphuric acid(2).

(2) Fisher, H.L., Conversion of rubber into thermoplastic products with properties similar to Gutta-Percha, Balata and Shellac, Ind. Eng. Chem. Vol. 19, 1927, p. 1325.

The material has been given the general name of "thermoprene" because the products have the thermo-plastic behavior of gutta-percha and balata of softening with heat. The change can be controlled so as to produce harder or softer products. It is stated that reclaimed rubber reacts so that this may be an outlet for old tires. The only material of this type which has so far been tried by the Bureau for core binders is "Vulcalock cement" prepared by the B. F. Goodrich Company, Akron, Ohio. It is rumored that similar materials made by others are, or will be available, but none has yet been tried by the Bureau. It appears very probable that a product of this general nature, as suitable for a core binder as the Vulcalock cement, but prepared with the special object of making a core binder might be produced by more economical methods than those required when the production of an adhesive is aimed at, and thus the price brought to a point where it might more readily compete with other core binders. Since balata-like thermoplastics are said to be produced by the acid treatment, the scope of the application of core binders of the balata type and avoidance of fire hazard, may be enlarged when such materials are available on the market. No development of the "thermoprenes" has as yet been made with core binders in view and the only experience with materials of this class as core binders at the Bureau has been with the commercial "Vulcalock" cement.

Core making with the special cement.

The sand should be dry and of suitable sieve analysis as discussed above. The Vulcalock cement is mixed with the sand as was described under plain cement. The sand, after proper mixing, does not stick to the core boxes even though the pure cement has strong adhesive qualities.

The sample of Vulcalock cement used, on mixing with a weighed amount of dry sand and drying to constant weight at 100°C lost 82%, indicating that it contained 18% thermoprene and 82% solvent. Diluting the Vulcalock cement with benzol to a 9% rubber solution and by using 3 1/2 parts of this to 40 parts sand (92 sand, 8 vulcalock) by volume, the strength developed is much greater than with the plain rubber cement. With Vulcalock, increasing the binder tends to give strength, whereas with plain rubber cement, the core tends to become too flexible if the amount of binder is increased too far.

Especially noteworthy is the high strength obtained with sand No. 2, see Table 1, Eight parts of a 9% Vulcalock cement by volume to 92 parts No. 2 sand on air drying 3 hours produced a core whose compressive strength was 105.0 lbs. per sq. in., and air drying 24 hours 89.2 lbs. per sq. in. The strength of an oil core used at the Washington Navy Yard made of 92 parts sand (3/4 No. 2 sand Table 1, 1/4 No. 1 sand Table 1), 4 1/2 parts flour, 3 1/2 parts linseed oil by volume, or 30 parts No. 2 sand, 10 parts No. 1 sand, 2 parts flour 1 1/2 parts linseed oil, sand tempered to 6% water, core baked at 200°C for 1 hour. This oil-flour core had a compressive strength of 86 1/2 lbs. per sq. in.

The effect of the great variation in compressive strengths of core sand mixtures depending on the percent of thermoprene in Vulcalock cement and air drying using one type of sand is shown in Table 4 below.

Table 4.

Rate of increase in compressive strength of Vulcalock cement cores using core sand No. 2.

40 parts sand, 2 1/2 parts (18% Vulcalock binder) by volume (94:6)

Time air drying after molding	Compressive strength lb. per sq. in.
At once	.5
1 hour	70.6
2 "	73.2
3 "	74.4
4 "	74.1
24 "	74.8

40 parts sand 3 parts (18% Vulcalock binder) by volume (93:7)

At once	1.3
1 hour	20.6
2 "	24.8
3 "	33.7
4 "	33.1
5 "	34.0
24 "	37.7

40 parts sand 3 1/2 parts (9% Vulcalock binder) by volume (92:8)

At once	Very weak
5 minutes	2.0
3 hours	105.0
24 "	89.2

40 parts sand 3 1/2 parts (7% Vulcalock binder) by volume (92:8)

At once	Very weak
5 minutes	2.0
3 hours	75.6
24 "	40.6

40 parts sand 3 1/2 parts (6% Vulcalock binder) by volume (92:8)

At once	Very weak
5 minutes	1.7
3 hours	59.1
24 "	37.4

Mixing plain rubber cement and Vulcalock cement.

Since high strength can be obtained by the use of Vulcalock cement, obviously graduations of strength can be secured by using suitable mixtures of the two. This is shown below:

Table 5.

Rate of increase in compressive strength of core sand mixtures of plain rubber cement and 18% Vulcalock cement using sand No. 2.

Time air drying after molding	40 parts sand 3 1/2 parts plain cement	40 parts sand 2-1/2 plain cement 1 part Vulcalock cement	40 parts sand 3 parts plain cement, 1/2 part Vulcalock cement.
	lbs.per sq.in.	lbs.per sq.in.	lbs.per sq.in.
At once	2.5	2.3	2.1
1 hour	5.7	7.0	6.7
2 "	7.5	9.4	8.8
3 "	8.8	12.3	11.1
4 "	9.0	16.7	15.3
24 "	8.1	17.9	16.4

Increase in compressive strength of core sand mixtures using No. 2 sand and 18% Vulcalock cement as a binder. Mix 40 parts sand to 3 1/2 parts Vulcalock cement. After core mix had been mulled thoroughly 50 cc of Benzol was added to further distribute the binder over the sand grains. Table below shows compressive strength of specimens molded when still wet with benzol, and specimen when molded more toward molding sand temper.

Table 6.

	Wet lbs.per sq.in.	Molding Temper lbs.per sq.in.
5 minutes	4.3	4.2
1 hour	35.1	48.3
2 "	61.4	106.6
3 "	168.3	125.4
4 "	220.2	132.7
5 "	244.7	150.2
24 "	286.9	162.1

The straight Vulcalock cement or the mixtures act similarly to the plain rubber or balata as to easy break-up of the bond after casting. However, the extremely strong Vulcalock cores do not disintegrate in lead castings but do in higher melting alloy castings. This is shown by items 13 and 14 in Table 7.

Items 3 to 8 were included to show the effect of clay bond, it will be noted that all the Bentonite-bonded specimens whether in cast iron or lead, were so hard after the metal was poured that they had to be chipped out of the castings. It will also be noted that the oil and flour core required chipping out from both metals.

Conclusion.

By use of the rubber, balata, or "thermoprene" type of core binders it is possible to make, without any baking, cores of strengths varying from perhaps double that of the ordinary green sand core to that comparable to the strength met in baked oil sand cores. The strength is very materially affected by the grain size (sieve analysis) of the core sand and it is not yet possible to state, without trial, whether a given core sand will be suitable for making high-strength cores with the rubber binders. By experiment and selection of the right sand and the right proportion of binder cores suitable for almost any sort of casting of any ordinary foundry alloy can be produced which will come away from the castings without the necessity of chipping-out.

The fire hazard is the chief drawback to the plain rubber and Vulcalock binders. This can be minimized by the use of balata.

The cost cannot be definitely stated. Milled smoked rubber at the moment of writing costs 20 cents to 30 cents or more a pound, depending on quantities purchased. Balata costs about twice as much. No quotation on Vulcalock cement for this purpose is available. On this the B.F.Goodrich Company should be consulted. Compared to the cost of linseed or other drying core oils, the cost of the rubber binders should not be out of reach and when the cost of cleaning out cores is considered, may show a saving. If the cores are found serviceable it may be expected that the binders will appear on the market so that the user may not be forced to make up his own solutions of rubber or balata.

Table 7.

Item	Sand Number (table)	Binder	Core Mixture Parts: Sand: Binder	Core Mixture Parts: Sand	Core Mixture Parts: Binder	Compressive Strength: Green strength just after molding lb./in²	Compressive Strength: 24 hours air drying lb./in²	Compressive Strength: Baked lb./in²	Permeability	Moldability	Metal Cast	Behavior of core on shaking out
1	1	Rubber	92:8	40	3 1/2	2.4	10.8		444	Very good	Iron	Very good, sand free flowing
2	1	Balata	92:8	40	3 1/2	3.0	12.1		376	" "	"	" " " " "
3	1	Bentonite	96:4	96	4	2.8-6% H_2O	19.8		325	Fair	Lead	No good, sand tooled out, Baked hard
4	1	"	96:4	96	4	2.9-8% "	23.8		257	"	Iron	" " " " " " "
5	1	"	92:8	92	8	5.7-4% "	16.8		347	Good	Lead	" " " " " " "
6	1	"	92:8	92	8	5.1-6% "	28.4		315	"	Iron	" " " " " " "
7	1	"	88:12	88	12	7.1-6% "	21.7		308	"	"	" " " " " " "
8	1	"	88:12	88	12	6.8-8% "	30.8		271	"	Lead	" " " " " " "
9	1	Vulcalock	92:8	40	3 1/2	2.2	22.8		449)	"	Lead	Baked, sand tooled out
10									)		Iron	Very good, sand free flowing.
11	2	Rubber	92:8	40	3 1/2	4.3	12.2*		202	Very good	Lead	Very good knocked out
12	2	Balata	92:8	40	3 1/2	2.6	8.8		178	Good	Lead	Good, knocked out
13	2	Vulcalock	92:8	40	3 1/2	3.5	135.0		136)	Very good	Lead	Sand tooled out, binder not entirely burned out.
14									)	" "	Iron	Very good, sand free flowing
15	30 parts No. 2: 10 parts No. 1: 2 parts flour: 1 1/2 parts linseed oil Tempered 6% H_2O, Baked at 200°C for 1 hour					.80	8.1	86.7	108)	Fair "	Lead Iron	Hard, had to be tooled out " " " " " "
			92:	(3 1/2 oil (4 1/2 flour								
16	3	Rubber	92:8	40	3 1/2	1.3	6.2		32)	Good	Lead	Very good, sand free flowing
17									)	"	Iron	" " " " "

Rubber binder = 1 lb. rubber in 2 gals. gasoline = approx. 7% rubber.
Balata " = 1 1/4 lb. balata in 1 gals. benzol = approx. 14 1/2% balata.

* 8.1 in another test, same sand but another lot of binder.