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RECENT DEVELOPMENTS IN THE WORLD SUGAR INDUSTRY[1/]

by

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INTRODUCTION

The object of the following report is to give an account of the main developments in the world sugar industry during the last decade.

These developments include the changing relations between sugar and other sweeteners and their influence on patterns of consumption and on the international location of the industry.

Recent price movements are reviewed and appraised in the light of the cost of providing new capacity.

Finally some account is given of current lines of research and recent achievements.

I. SUGARS AND SWEETENERS

The essential characteristic of a sugar is its sweetness and the sweetness of the various sugars is usually expressed in terms of sucrose equivalent. Sucrose is the pure chemical extracted from the juice of the sugar cane or of the beet, the final stage of purification being that of crystallisation and the separation of the sucrose crystals (by centrifuge) from the mother liquor leaving a syrup - molasses - which does not crystallise. A second important characteristic of a sugar is accordingly its purity. In many developing countries where sugar is mainly required for household uses a high degree of

purity is not required and a substantial part of their output falls into the general category of non-centrifugal sugars.

Chemically, sugars are carbohydrates, i.e. composed solely of carbon hydrogen and oxygen, the two latter elements in the proportion of two to one as in water, and sucrose belongs to the class of disaccharides as do lactose and maltose having about one third the sweetness of sucrose. Disaccharides are characterised by the ease with which they break down by hydrolysis under the influence of dilute acids or of enzymes into monosaccharides according to the equation

$$C_{12}H_{22}O_{11} + H_2O = 2.C_6H_{12}O_6$$

Typical monosaccharides of the hexose (six oxygen atoms) variety are glucose and fructose and the above equation illustrates the hydrolysis of maltose to give two molecules of glucose. Most disaccharides however hydrolyse into more than one monosaccharide in particular sucrose into glucose and fructose but as the general formula for all disaccharides and all hexose monosaccharides is the same this difference is not revealed by the above equation which obscures the complexity of the molecules and reactions involved.

Although this complex structure can only be adequately represented in stereo fashion the disposition of radicles within the various sugars may be shown as follows:

Glucose $CHO-CHOH-CHOH-CHOH-CHOH-CH_2OH$

Fructose $CH_2OH-CO-CHOH-CHOH-CHOH-CH_2OH$

Glucose has an aldehyde group CHO attached to the alcohol CHOH groups while fructose has instead a keystone group CO. These differing configurations give rise to different properties, for example the sweetness of glucose is about 0.7 compared with sucrose while that of fructose is about 1.2 in average conditions. Again the asymmetric arrangement of the radicles indicates optical activity, the glucose configuration turning the plane of polarised light to the right whence the alternative name dextrose while a solution of fructose (levulose) turns it to the left. Other common monosaccharides with different configurations are glycerol and sorbitol, both with about half the sweetness of sucrose. Sorbitol is widely used as a food preservative.

The sucrose molecule is dextro-rotatory a property which is used to determine by polarimeter the sucrose content of juice. The molecule consists of a glucose molecule linked to a fructose molecule through two hydroxyl groups with the elimination of H_2O and as in the case of the two latter would normally occur in ring form rather than in the straight chain form indicated above.

The simple hydrolysis reaction converting sucrose to glucose and fructose is used to make invert sugar which changes the direction of optical rotation whence the name

invert. This liquid sugar is widely used in the manufacture of confectionery where softness in the finished product is required. Since the ferments or enzymes which cause this reaction are always present in the atmosphere it will proceed whenever conditions are favourable e.g. with impure sugar; pure sugar will not ferment because of the absence of the nitrogen associated with impurities. The reaction may proceed to the extent of converting the sugar into alcohol or eventually into acetic acid.

The higher polysaccharides which are not sugars include as their most important members cellulose and starch. The molecules are complex but are normally indicated by the simple formula $(C_6H_{10}O_5)_n$. Starch from maize is extensively used in making glucose by a simple reaction with dilute acid and the crystals of glucose can be obtained although it is more usually used in the form of a syrup (corn syrup). More recently with the use of suitable enzymes high fructose syrups have been developed which are much sweeter and tend to replace liquid sugar.

A third highly important characteristic of a sugar is its nutrient value given in terms of calories. It has been calculated that an acre devoted to the cultivation of sugar cane is capable of producing more calories than any other food crop and is the cheapest source of calories known. Sugar is all energy however; it contains no proteins or vitamins.

Sugars or more accurately sweeteners are accordingly divided into nutrient and non-nutrient (non-caloric) types. The principal non-nutrient sweeteners at present in commercial use are saccherin and cyclamate with respectively 300 times and 30 times the sweetness of ordinary cane sugar under similar conditions. They are chemically quite different from the carbohydrates. They are inexpensive in terms of sweetness but the possibility of undesirable side effects is always under examination and currently only saccherin is allowed as a food sweetener in the U.K. although in the U.S.A. it was very recently banned.

II. CONSUMPTION

During the five years 1969/70 to 1973/74 inclusive, world consumption of centrifugal sugar increased at an average rate of 3.1 per cent per annum. This compares with a rate of increase of 3.9 per cent ten years earlier and is considered to be due partly to declining rates of population growth and partly to lower income elasticities of demand. Such concepts are however only meaningful in relation to the circumstances of particular countries and even to particular end uses.

There is of course a great variation in sugar consumption per head of population in different countries reflecting primarily differences in income level but also consumption

habits. Thus in recent years it has averaged about 50 kg per head in the United States, the United Kingdom and Scandinavia, about 55 kg in Australia and New Zealand and about 65 kg in Israel. For most other European countries and for Latin America it averages about 40 kg while in India it falls to about 7 kg and in China to about 4½ kg. Moreover, while consumption per head in recent years has been virtually stationary in the Western world and population increasing only slowly, consumption per head in the developing world is increasing at about 3½ per cent per annum and population at about 2½ per cent. The share of the developing world in sugar consumption has increased accordingly from about 37.7 per cent in 1969/70 to 39.2 per cent in 1973/74.

The slowest rate of growth during this period was in the United States averaging only 1.2 per cent per annum but this was partly due to competition from corn syrups and sweeteners as the following figures illustrate:

U.S.A.: Consumption per head of Sweeteners (lbs)

	1961	1971
Sucrose	97.7	102.4
Corn syrup and Dextrose	14.3	21.4
Other caloric	2.2	1.7
Non-caloric (Sucrose equivalent)	2.5	5.7

The share of sucrose fell during those ten years from 83.7 per cent to 78.0 per cent. Corn based syrup is very much cheaper than refined sugar and in competition with liquid sugar and other refined sugars is steadily increasing its share of the industrial market especially in bakery and confectionery uses. Sucrose has virtually the whole market for household uses which however is now less than half the industrial market and until recently had maintained its predominance in brewing and canning uses. This is now threatened by the new high fructose syrup. The market for dextrose used in the manufacture of the low calorie food preservative sorbitol is also an expanding one. A continuation of existing trends in the United States would suggest therefore no further increase in sugar (sucrose) consumption beyond present levels. The expanding market would be taken up by non-caloric sweeteners and corn syrups, in particular high fructose syrup which by 1980 may alone account for over 10 per cent total consumption. While the United States leads in these developments, the trend in Western Europe and to a lesser extent in other countries is in the same direction e.g. it is estimated that by 1980 high fructose syrups will amount to over 5 per cent of total sweetener consumption.

In 1974 sugar prices rose to record levels and helped to bring about a fall in consumption especially in the United States where consumption per head fell by 2.7 per cent from the 1973 level. Consumption per head in the developing world fell

slightly although total consumption continued to increase. The heavier fall in the United States and high income countries was partly due to continuing inroads by other sweeteners accentuated by the high sugar prices but price elasticity - in the U.S.A. estimated at between -0.15 and -0.18 - was also effective. In the lower income developing world it is probable that the high income elasticities were sufficient to offset the influence of prices.

In general prices have exercised a strong influence on sugar consumption and production. The very great increase in world consumption from just over 30 million tons to just over 80 million tons in the twenty years ending 1974 although largely due to the steady rise in population and incomes was also due to the low price of sugar which according to the FAO fell during this period by 40 per cent in real terms.

Any forecast of future sugar consumption has to take account therefore of price movements as well as income growth and competition from other sweeteners. Estimates for 1980 have accordingly been made between 92 and 94 million tons at high and low prices of which developing countries are likely to account for about 44 per cent. In more detail FAO have made two estimates the lower based on the assumption that real sugar prices remain at 1973 levels in which case 1980 output would be between 92½ and 94 million tons and 1985 output at 108 million. If prices rose by 10-25 per cent then 1980 consumption would be between 83½ and 89½ million tons and 1985

consumption about 104 million. Other estimates based on a continuation of past trends give 92.3 million for 1980 while a realistic appraisal of existing development plans are in the range 92-95 million representing a considerable fall from that envisaged by development plans current in 1975.

III. PRODUCTION AND TRADE

Sugar production has responded to price movements partly as a result of their reaction on raw material prices and output and partly in relation to the steadily increasing capital cost of new factories. For the world as a whole of course production keeps in line with consumption, the difference resulting in stock changes. In the early 1960s stocks were high at about 30 per cent of annual consumption but during the four years ending 1973/74 consumption increased more rapidly than production and stocks fell to 19.4 per cent of current annual consumption. At this point a very sharp riss in prices occurred which checked consumption so that stocks increased once more and price fell to 1973 levels. (see below).

In 1974/75 consumption was 3.4 per cent less than in 1973/74 and stocks rose to 23.3 per cent of current annual consumption. In 1975/76 production was again larger than consumption, stocks increased to 25.3 per cent of current consumption and prices continued to fall.

The proportion of sugar production entering international trade is slowly falling; from 32.8 per cent in 1971/72 to 30.7 per cent in 1974/75 and 27.1 per cent in 1975/76. In total up to 1975/76 the figure for world trade has changed very little in recent years but there has been some increase in net trade as a result of imports and exports becoming less balanced; in 1975/76 both gross and net world trade fell by about 10 per cent.

The structure of net imports in 1974/75 was for 60 per cent to go to four countries namely U.K., U.S.A., Japan and the Soviet Union and for 50 per cent of exports to come from Cuba, Brazil, Philippines and Australia all cane sugar exporters and for this concentration to increase. Exports of beet sugar from Western Europe are increasing although the area remains an increasing net importer of sugar. In 1975/76 however imports into Western Europe declined as did exports from Latin America.

The supply of sugar and allied products consists of beet sugar, cane sugar, non-centrifugal sugar and molasses. Cane sugar which in effect represents the production of developing countries has increased over the years relative to beet sugar especially when beet sugar production has been checked by war or depression. During the twenty years ending 1972/73 beet sugar accounted for about 42 per cent of sugar production falling with the depression to 40 per cent, then to 37 per cent in 1974/75 and rising once more to 40 per cent in

1975/76. It may be noted however that in Japan and China where both cane and beet are grown, the share of beet has been increasing.

Production of non-centrifugal sugar currently amounts to about ten million tons per annum considered equivalent to 5 million tons of raw sugar. Many countries are involved but India accounts for about 60 per cent of output and Pakistan for a further 15 per cent.

Molasses output at about 27 million tons per annum is in step with sugar production amounting to about one third; the proportion is somewhat lower in Europe and higher in Asia reflecting sugar extraction rates.

In the essentially mechanical process of sugar extraction, the presence of impurities in the juice affects the amount of sucrose which can be obtained according to the relation:

> % Sucrose recoverable = % Sucrose available less one half of the % of impurities in the juice.

There is however an increasing tendency in developed countries to use chemical methods to obtain a higher additional yield i.e. desugarising molasses.

The purity of the juice is indicated by the polarimeter according to the relations:

Polarity of juice	=	% of Sucrose in juice
Purity of juice	=	% of Sucrose dissolved in juice
Brix of juice	=	% of all solids (Sucrose Sucrose impurities) dissolved in juice
Purity x Brix	=	Polarity

The modern system of sugar manufacture in Western countries is based on economising on materials, fuel and labour through capital investment. Accordingly a high degree of extraction is sought at the milling stage through increasing the number of crushers; water and indirectly fuel is saved by counter current flow and heat is directly saved by using the latent heat of steam in a succession of vacuum evaporators. Where sugar cane is locally grown, where labour is cheap and where bagasse is available (as it is) in sufficient quantity to fuel the most inefficient use of heat these economies are less necessary and the system of production of modified accordingly.

IV. PRICES AND COSTS

The course of sugar prices - New York spot quotations in cents per lb for raw sugar - during the last ten years have been as follows:

	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967
Jan	14.06	38.33	15.32	9.40	8.24	4.73	3.12	2.95	2.20	1.35
Feb	13.52	33.72	21.28	9.06	8.01	4.83	3.23	3.23	2.17	1.71
Mar	14.92	26.50	21.27	8.89	8.72	4.71	3.44	3.70	1.93	1.61
Apr	14.06	24.06	21.77	9.06	7.28	4.61	3.62	3.76	1.84	2.10
May	14.58	17.38	23.65	9.67	7.00	4.35	3.75	3.78	1.98	2.39
Jun	12.99	13.83	23.67	9.77	6.57	4.14	3.82	3.95	1.78	2.52
Jul	13.21	17.07	25.40	9.81	5.57	4.20	3.86	3.72	1.71	1.90
Aug	9.97	18.73	31.45	9.09	6.27	4.38	3.89	3.10	1.66	1.68
Sep	8.17	15.46	34.35	9.01	7.03	3.99	3.93	3.10	1.45	1.60
Oct	9.07	14.10	39.93	9.56	7.40	4.18	3.99	3.12	1.90	2.15
Nov	7.09	13.10	57.17	10.14	7.23	4.20	4.18	3.08	2.39	2.32
Dec	7.53	13.30	44.97	11.83	9.07	5.93	4.16	2.86	2.77	1.77

From the 1974 boom prices have now fallen back to 1972 levels. In the meantime however prices generally and machinery prices in particular have continued to increase with inflation so that it is now doubtful whether investment in sugar production at present prices is profitable.

It has been stated that a minimum price for raw sugar of 10 cents per lb (refined sugar 15 cents per lb) is necessary to justify the installation of new capacity. In 1974 it was calculated by UVA that the construction of a new integrated plantation and sugar factory would involve a capital expenditure of $800 per annum ton of sugar of which about half would be for the factory and half for the plantation. An estimate by ISO in 1975 gave £250 million for a large factory producing 6000 tons of sugar per day equivalent to about $300 per annual ton. Taking the higher price which is probably more appropriate to normal sized factories then a 15 per cent gross return on capital would absorb 5 cents per lb which suggests that wages and materials are reckoned at about 10 cents per lb. If this is so and if machinery prices have increased still further (the large integrated plant in the Sudan now under construction is estimated to cost about $1400 per annual ton) then current sugar prices are too low.

It may be the case however that these vast integrated plants are unduly expensive. The smallest centrifugal sugar plant now operating has a capacity of only 50 tons of cane per 24 hours and the largest 26,000 tons so that alternative

technologies to those advocated by the Western multinationals probably exist. In particular machinery is now readily available from non-western sources - India, China, Brazil, Mexico and probably Cuba are self-sufficient in this respect while India is currently constructing a plant in Kenya, China in Mali, Taiwan in Indonesia, Liberia and Gabon and Turkey in Tunisia. It is probable that machinery for the smaller plants can be obtained more cheaply from these sources and it is of course a general rule that the less sophisticated the technology the greater the competition among suppliers of machinery. One reason for the existence of small plants is the availability of cane. On the other hand it is possible as in Venezuela to store juice centrally for large scale processing provided that at the clarification stage sufficient lime has been added to bring the pH above 7 and that the juice is sufficiantly concentrated.

Another question arising at present is whether in view of increasing capital costs new corn syrup capacity should be constructed. This is a particularly important issue in the case of high fructose syrup which has the same outlets as liquid refined sugar with a quality discount in price at present of about 20 per cent. Recent New York prices quoted by the Journal of Commerce have been as follows:

	Refined Sugar	Corn Syrup		Dextrose		High Fructose
	cents/lb	cents/ lb	$/ cwt	cents/ lb	$/ cwt	$/cwt
Av. 1970-3	12.9	7.9	8.0	10.4	10.5	..
1974	34.4	13.2	13.2	12.2	..	..
1975	31.4	18.0	18.1	21.0	22.4	23.1
1st half 1976	21.3	16.0	15.3	16.9	16.9	15.1

The margin between refined sugar prices and raw suger prices rose from about 6½ cents per lb in 1970-3 to 11 cents in 1975 and has since reverted to former levels. The price of corn syrup as a percentage of refined sugar prices fell from 61 in 1970-3 to 38 in 1974 and then rose to 75 in the first half of 1976. High fructose syrup prices have been steadier at about 74 per cent of refined sugar prices. These movements clearly do not reflect changes in costs of production; the normal cost of refining is about 5 cents per lb from raw suger while high fructose should normally cost about 1½ cents per lb more than standard corn syrup.

Estimates of normal costs of production involve raw material prices, capital (new plant) costs and processing costs. In the case of sugar the raw material whether cane or beet but especially the latter is in competition with other crops whereas corn requirements of syrup are small compared with other outlets. New plant capital costs are strongly

influenced by scale. Sucrose production is usually large scale at $300-400 per annual ton and syrup plant costs are in the same general area from $240 to $400 per ton depending on scale which especially affects the wet milling process used in the production of starch. In relation to this the capital cost per ton of output of the hydrolysing process from starch to glucose and the further stage of isomerisation from glucose to high fructose are fairly small.

The consensus appears to be that the minimum ex-mill price at which high fructose syrup can be produced in a new plant with corn at $3 per bushel i.e. 5 cents net per lb starch is about 10 cents per lb. For beet sugar about 8½ cents per lb net in terms of sugar content would have to be paid for beet so that with processing costs about the same high fructose syrup would be at an advantage whatever sugar prices were. It is also the case that after allowing for transport and selling charges current New York prices are too low to justify investment in new capacity in either. They might not be too low however to deter some of the more efficient cane sugar producers in developing countries in which case problems of protection might arise.

V. RESEARCH

The current high price of hydrocarbons e.g. oil and natural gas has encouraged research into the possible use of

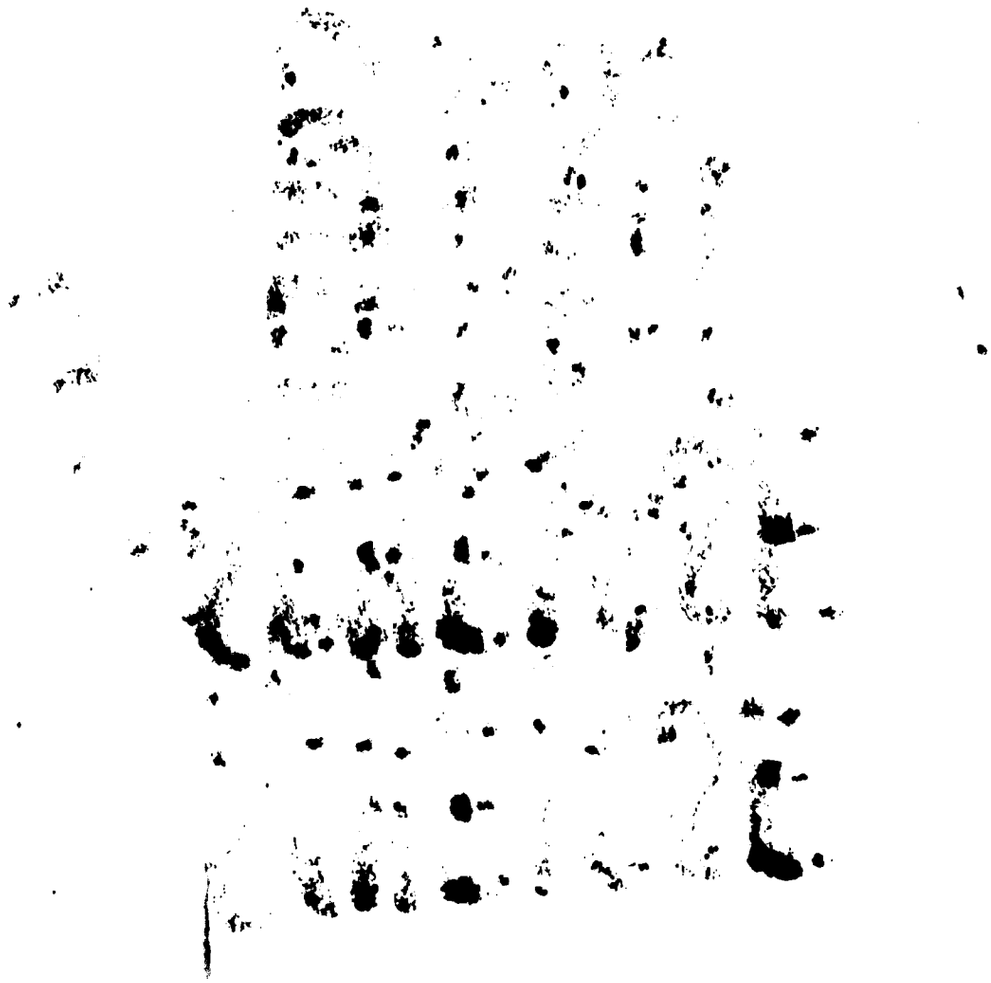
carbohydrates and in particular sucrose as substitutes in various chemical processes. The manufacture of products such as surfactants plastics, adhesives, agricultural chemicals, pharmaceuticals and food additives with a carbohydrate base has been investigated and a sucrose surfactant is already in commercial production

A main field of research in the sugar industry has always been that relating to enzymes and fermentation technology generally for example the production of glucose syrup from starch (using amylase) of invert sugar (invertase) and more recently fructose enriched syrup (isomerase). Enzymes are expensive to produce and research is currently directed towards the technology of applying them economically.

At the same time the scope for enzyme chemistry is being extended to include the hydrolysis for glucose production of cellulose e.g. bagasse, the conversion by a suitable enzyme (amylase) of crude starch containing materials, into partially hydrolysed starch thus cutting out the expensive wet milling process and the reduction of the higher saccharides present in syrups into glucose by means of other enzymes (pullulenase) thus producing a richer high fructose syrup HFFS.

Research directed towards producing non-toxic and more intensive sweeteners has brought near to commercial development new synthetic sweeteners, some of high intensity and also naturally occurring protein sweeteners based on West African plants. More basic research is directed towards discovering

why molecules are sweet and which part of the complex molecules involved is responsible for the sweet taste.



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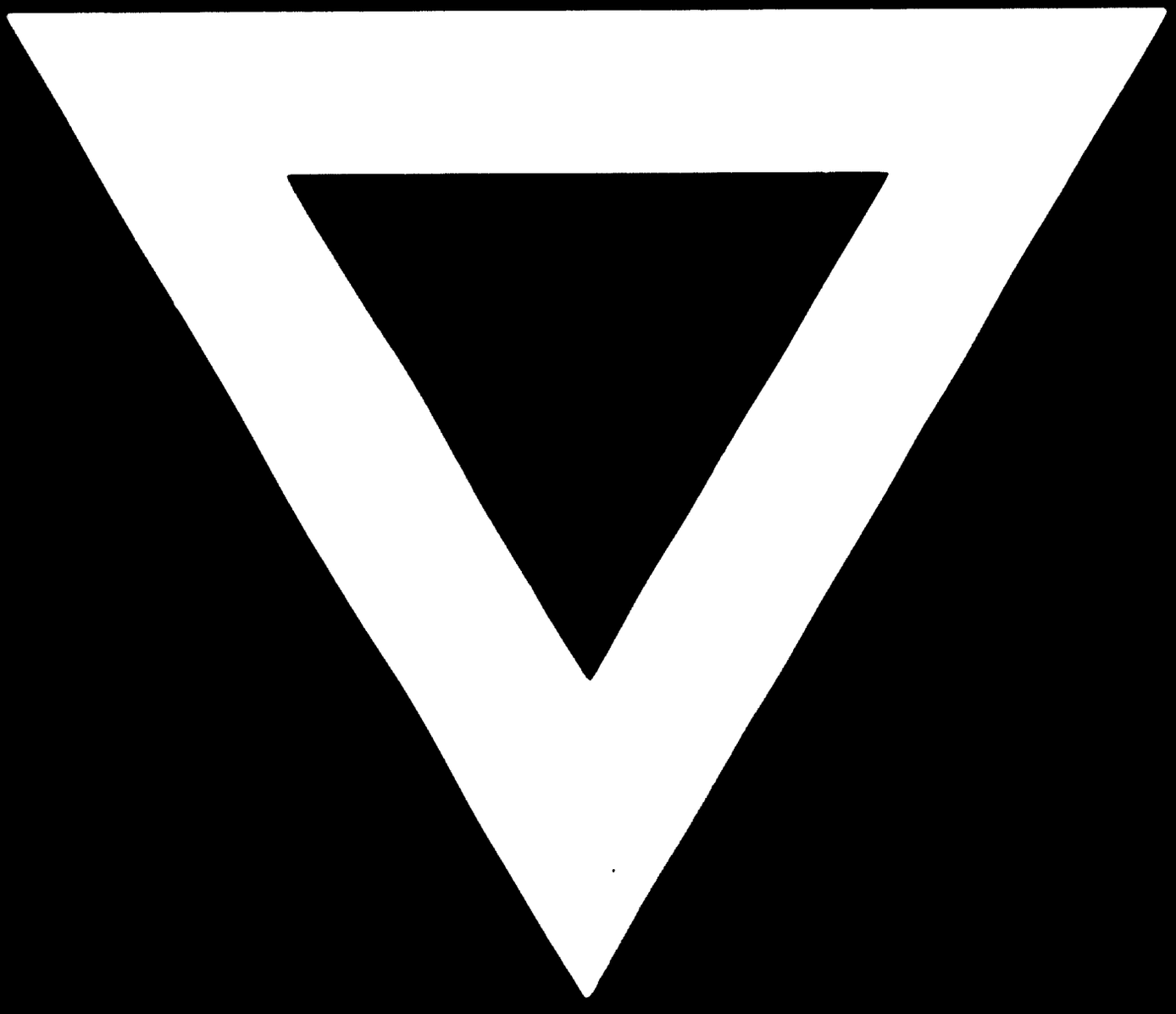

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