

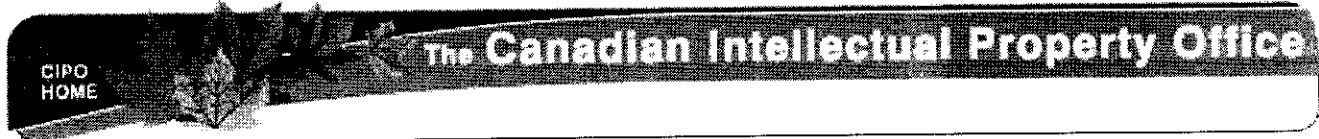


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(12) Patent:

(54) CARBON MONOXIDE CONVERSION CATALYST AND METHOD OF PREPARING SAME

(54)

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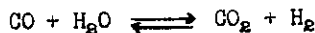
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1 This invention relates to catalytic materials for use in
2 carrying out chemical reactions between gases, to methods of preparing
3 the same and to commercial processes using such catalytic materials.
4 More particularly, this invention relates to chromium oxide-promoted
5 iron oxide catalysts to be used in the water-gas shift reaction for
6 the production of gaseous mixtures containing carbon monoxide, carbon
7 dioxide and hydrogen by passing a mixture of gases containing carbon
8 monoxide and water vapor over said catalyst at elevated temperatures;
9 to methods of preparing such an improved catalyst; and to the
10 commercial processes employing such a catalyst.

11 In the water-gas shift process which may be represented by
12 the following equation



14 many catalytic materials having widely varying chemical compositions
15 have been employed and, although commercial success has been noted in
16 the case of some of these materials, considerable room for improvement
17 still exists in this field.

18 For example, a catalyst, in order to be usable on a commercial
19 scale, must not only have a high enough crush strength to resist
20 disintegration, crushing or crumbling during handling and loading
21 operations, but it must also maintain its crush strength during actual
22 usage under commercial reactor conditions. If such a property were
23 absent, the catalyst would be rapidly reduced to a state of fineness
24 and dustiness which would seriously reduce gas velocities and
25 drastically decrease plant throughput.

26 A principal purpose of the present invention is therefore to
27 prepare an improved catalyst of an extremely rugged nature and capable
28 of resisting such fragmentation and disintegration.

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1 Additionally, a catalyst should possess a high activity on a
2 volume basis whereby a smaller catalyst volume for a given purpose
3 would be required, consequently rendering possible the use of smaller
4 and less expensive convertors for equivalent purposes. Such a factor
5 would be highly valuable in presently-operating, fixed-volume conver-
6 tors wherein the use of such an improved catalyst would enable an
7 increase in plant capacity without installing additional convertors.

8 In addition to high activity, the catalyst should also have
9 good thermal resistance whereby only a small loss of activity is
10 observed when it is subjected to high temperatures, such as are
11 encountered in commercial operations.

12 In a similar way, it is desired that the activity of the
13 catalyst also remain high at low temperatures inasmuch as, for any
14 specific steam:gas ratio, the yield of hydrogen is increased and the
15 carbon monoxide is more completely converted to carbon dioxide at such
16 low temperatures. At the same time, low water to carbon monoxide
17 ratios are desirable inasmuch as the decreased water requirement
18 provides for substantial savings in capital investment and operating
19 costs.

20 Another principal purpose of the present invention is there-
21 fore to prepare an improved catalyst having a high activity on a
22 volume basis, particularly at low temperatures, accompanied by good
23 thermal resistance whereby increased capacity and improved yield per
24 convertor volume is attained and maintained in commercial operation,
25 as well as a low water to carbon monoxide ratio as low as about 3 or
26 4 to 1.

27 At the same time, a low bulk density is desirable in such a
28 catalyst inasmuch as a smaller weight of catalyst will be required for
29 a given convertor volume. This will result in a substantial saving in
30 catalyst cost inasmuch as catalyst is sold on a weight basis.

1 Still another principal purpose of the present invention is
2 therefore to prepare an improved catalyst of low bulk density.

3 Such catalysts should furthermore possess high resistance to
4 any undesirable effects of exposure to liquid water, such as would
5 be present due to the condensation of the steam used in the process.
6 The catalyst should resist disintegration or dissolution under such
7 moisture conditions to prevent impeding the normal flow of the gases
8 which could bring about expensive and time-consuming shutdowns and
9 replacements of the catalyst.

10 Additionally, the catalyst should possess a high resistance to
11 impairment and/or breakdown when used with a gas having a relatively
12 high concentration of impurities such as sulfur compounds or acetylene,
13 kerosene and the like.

14 It is therefore a further principal object of the present
15 invention to prepare a catalyst having improved resistance to liquid
16 water, kerosene, sulfur compounds, or unsaturated materials such as
17 acetylene, and the like.

18 It has been found that the above-mentioned purposes may be
19 accomplished by means of an improved carbon monoxide convertor
20 catalyst which may be prepared by forming an intimate moistened mixture
21 of iron oxide and ammonium dichromate or ammonium chromate, forming
22 the mixture into shaped configurations, if so desired, and drying the
23 mixture. The dried mixture may then be calcined and is then ready
24 to be loaded into the reactors for actual commercial use.

25 The chromium-containing compound may be mixed with the iron
26 oxide by any conventional method such as, for example, by dissolving
27 the chromium-containing compound in water or other suitable solvent
28 and then spraying the resulting solution on or otherwise mixing it
29 with the iron oxide, which is preferably in powdered form, until a
30 wet slurry or moist mixture is formed. Additional iron oxide powder

1 may then be added, as desired, and the wet slurry mixed constantly
2 and thoroughly until the proper or required consistency for molding
3 or other working is attained. Another method of preparation, for
4 example, would comprise a dry mixing of the ammonium dichromate or chro-
5 mate with the iron oxide, followed by the addition of sufficient water to
6 moisten or wet down the mix to form a plastic mass of the proper con-
7 sistency. The moldable mass, as prepared by these or other equivalent
8 processes, may then be dried and granulated or, if desired, may be
9 shaped into any desired configuration, while still moistened and
10 moldable, such as by being extruded, formed into thin sheets, pelleted
11 or tableted and then dried. The dried product is then calcined at
12 temperatures of from about the decomposition temperature up to about
13 1200°F. in order to decompose the chromium-containing compound into
14 chromium oxide and non-objectionable gases, the latter being readily
15 removed.

16 The amount of the chromium-containing compound which is added
17 to the mix should be such that the calculated chromium oxide (Cr_2O_3)
18 content of the finished catalyst falls within a range of from about
19 0.5% up to about 15% by weight on a dry basis with the iron oxide
20 having a minimum concentration of about 85% by weight. The percentage
21 of the chromia content depends upon many factors such as the contem-
22 plated use of the catalyst, the desired promoter effect, the nature
23 of the gaseous mixture which is to be converted, etc., and we have
24 found that in the normal case a range of from about 3% to about 7%
25 of chromium oxide by weight with the maximum concentration of iron
26 oxide being about 97% by weight is preferred.

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1 A conventional water-insoluble lubricant may be added to the
2 plastic mixture in order to facilitate the pelleting, extruding or
3 other forming of the catalyst. The quantity of water-insoluble
4 lubricant added depends to a large extent upon its properties and
5 general effectiveness as well as upon the particular characteristics
6 to be imparted to the plastic mixture. However, in general, we have
7 found that from about 0.1% to about 10% by weight of water-insoluble
8 lubricant is preferred. Although the invention will be described
9 primarily with graphite as the preferred lubricant, such is not to be
10 construed as limitative of the invention, inasmuch as other lubricants
11 may be employed such as: talc; colloidal clay; hydrocarbon oils and
12 waxes; higher molecular weight fatty acids (stearic, palmitic, oleic,
13 etc.); esters of higher molecular weight fatty acids such as, for
14 example, the glycerides of such acids; the insoluble salts of the
15 higher molecular weight fatty acids, notably the zinc, magnesium and
16 calcium salts, and the like. The amount used of any particular
17 lubricant will vary as to its specific characteristics and it has been
18 determined that graphite, for example, functions best in concentra-
19 tions of from about 0.5% to about 10% by weight. Magnesium stearate,
20 on the other hand, may be used in a percentage range of 0.1% to about
21 4.0%, for example.

22 The invention will be further described in greater detail by
23 the following specific examples. It is to be understood, however,
24 that although these examples may describe in particular detail some
25 of the specific features of the invention, they are given primarily
26 for purposes of illustration and the invention in its broader aspects
27 is not to be construed as limited thereto.

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EXAMPLE 1

1
2 3.9 pounds of ammonium dichromate was added in the form of a
3 hot 18% solution to approximately 50 pounds of red iron oxide powder
4 in a small, pan-type mixer. The solution was thoroughly mixed for
5 about 15 minutes and then approximately 10 pounds of additional red
6 iron oxide was added in order to granulate the mix. This was
7 followed by the addition of approximately 5 pounds of a lubricant,
8 such as graphite. The moist plastic mixture was then extruded through
9 a 9/32 inch die, dried for approximately two hours in an air oven at
10 a temperature of about 280°F. and calcined for more than one hour at
11 1100°F. The amount of ammonium dichromate added in this particular
12 form was sufficient to yield a catalyst containing approximately 3.8%
13 chromia (Cr_2O_3) by weight.

14 The chemical analysis of this particular convertor catalyst
15 was as follows:

TABLE I

17	L.O.I.	0.5%
18	Fe_2O_3	95.0%
19	Cr_2O_3	3.8%
20	SiO_2	0.2%
21	SO_3	0.2%

EXAMPLE 2

1
2 500 pounds of a pigment-grade iron oxide, such as Williams
3 R-1599 red iron oxide, was charged to a conventional type muller.
4 This particular material was a very active iron oxide which was
5 thermally stable and was made by the thermal decomposition, under
6 controlled oxidizing temperatures, of ferrous sulfate, followed by
7 water grinding and washing to eliminate traces of soluble salts. With
8 the mixer on, 225 pounds of a promoter solution comprising an 18%
9 solution of ammonium dichromate $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$ prepared from 40 pounds
10 of ammonium dichromate and 181.5 pounds of water was rapidly added
11 to the iron oxide in the muller. The solution and the iron oxide
12 were allowed to mull for approximately 10 minutes. Then an additional
13 150 pounds of red iron oxide was added over a 10-minute period and
14 the mixture was allowed to mull for an additional 10 minutes. At the
15 end of that time, the mixture was in a granular state. 20 pounds of
16 graphite as a lubricant was then added and the damp mixture was
17 extruded with the cutter set at 200 r.p.m. (a reading of 400) using a
18 multihole die in which the holes had a diameter of $19/64$ inch. The
19 cutter speed was so adjusted that the average pellet length was
20 approximately $1/4$ inch to about $3/8$ inch. The extruded product was
21 transferred to a small belt drier and run into an indirect fired
22 kiln maintained at a temperature of from about 500°C . to about 620°C .
23 Calcination for about one hour took place and the calcined pellets
24 were discharged to be screened and then stored or packaged, as
25 desired.

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EXAMPLE 3

1
2 600 grams of red iron oxide (Fe_2O_3), 50 grams of ammonium
3 dichromate and 260 ml. of water were used to prepare a moldable mix
4 as follows: The ammonium dichromate was dissolved in 150 ml. of
5 water. The iron oxide was placed in a suitable container and
6 positioned on the kneading machine. The ammonium dichromate solution
7 was then added to the iron oxide while continuously kneading. 110 ml.
8 of water was then added and the kneading continued until a workable
9 mixture was obtained. The mixture was placed in a tray drier for
10 approximately 4 hours and was maintained at a temperature of approxi-
11 mately 240°F. The dried mixture was then broken into particles
12 approximately 5-10 mm. in size and placed in a muffle furnace main-
13 tained at a temperature of approximately 1100°F. for approximately
14 two hours. The resulting calcined catalytic material had a chromia
15 content of approximately 5% by weight.

EXAMPLE 4

16
17 600 grams of a pigment grade iron oxide, such as Williams
18 R-1599, 100 grams of ammonium dichromate and 250 ml. of water were
19 used to prepare a chromia-promoted catalyst having a chromia content
20 of approximately 10%. The ammonium dichromate was dissolved in 200 ml.
21 of warm water and the solution was added to the iron oxide with
22 continuous intermixing. 50 ml. of water was then added and the
23 mixture was kneaded until a workable mixture was obtained. The
24 mixture was removed from the kneader and placed in a tray drier
25 maintained at a temperature of approximately 240°F. for approximately
26 four hours. The dried cake was removed from the drier and broken into
27 particles approximately 5 to 10 mm. in size and screened. This mater-
28 ial was then placed in a muffle furnace maintained at a temperature
29 between 940°F. and 1100°F. for a period of approximately two hours.
30 The resulting catalyst had a chromia content of approximately 10% by
31 weight on a dry basis and possessed good resistance to sulfur gases,
32 acetylene and kerosene.

EXAMPLE 5

1
2 50 pounds of a pigment grade red iron oxide, and a solution
3 formed from 4.43 pounds of ammonium dichromate and 20 pounds of water
4 were used to prepare an extrudable mixture as follows: The solution
5 was added to the iron oxide with continuous agitation. 7.5 pounds
6 of iron oxide and 0.5 pound of graphite were then added and the
7 entire mixture agitated. The mixture was then extruded into pellets,
8 dried for two hours at approximately 280°F. and then calcined for
9 approximately 1 hour at 1100°F. Several samples of the pellets were
10 analyzed and found to have a chromia content between 3.9% and 4.1%.

EXAMPLE 6

11
12 66 pounds of a pigment grade iron oxide (Williams R-1599),
13 25 pounds of a 17.5% solution of ammonium dichromate and 2 pounds of
14 graphite were used in order to form an extrudable mixture for the
15 chromia promoted iron oxide catalyst. The total mixing time was
16 approximately 20 minutes. The extrusion took place through a multi-
17 hole die (38 holes) with the diameter of each hole being 19/64 inch
18 with a cutter reading of 250. The material extruded very easily with
19 practically no sticking.

EXAMPLE 7

20
21 50 pounds of a pigment grade red iron oxide, such as Williams
22 R-1599, and a solution formed from 5.34 pounds of ammonium chromate
23 and 20 pounds of water were used to prepare a moldable mixture
24 suitable for calcining into a catalyst for the production of hydrogen
25 and carbon dioxide by the reaction of carbon monoxide and water vapor.
26 The solution was added to the red iron oxide with continuous agitation.
27 7 pounds of additional red iron oxide and 0.5 pounds of graphite were
28 added and the entire mixture agitated. The mixture was then dried
29 for approximately 2 hours at a temperature of about 280°F. and then
30 calcined for approximately 1 hour in a muffle furnace maintained at

1 a temperature of approximately 1100°F. Several samples of the result-
2 ing product were analyzed and found to have a chromia content of
3 approximately 4.2% by weight.

4 In the following testing of the catalyst of the present inven-
5 tion, an "aged" catalyst is defined as one which has been aged for
6 16 hours at a temperature of about 625°C. in flowing gas (35% CO and
7 65% H₂) (SV=200/hr.) plus steam (SV=1370/hr.).

8 The effect of kerosene vapors in the gas stream on the
9 activity of the catalyst of the present invention was determined as
10 follows: A reactor was packed with approximately 550 cc. of aged
11 catalyst. A cup containing liquid kerosene was fitted in a tee to
12 the gas line carrying the gaseous mixture to the reactor. After
13 approximately 45 hours of operating time, a water bath was placed
14 underneath the kerosene cup and the temperature of the water was
15 heated to and maintained at approximately 100°C. This was done in
16 order to evaporate a considerable quantity of kerosene and to test
17 the catalyst under conditions more severe than could be expected.
18 The entrainment of kerosene vapors during the run was approximately
19 2.4 lbs. of kerosene per 20,000 lbs. of gas.

20 The conditions during the run were as follows: the space
21 velocity (STP) was 770/hr; the steam to gas ratio was 1.13:1; the
22 reactor pressure was 100 psig; and the feed gas had an approximate
23 composition of 60% hydrogen, 28% carbon monoxide, 6% methane, 6%
24 carbon dioxide, 0.2% acetylene and 0.2% oxygen.

25 The percent of carbon monoxide conversion was checked for 77
26 hours at 425°C. and found to be 81.3% and then checked for 17.5 hours
27 at 375°C. and found to be 40.5%. The results so obtained agree approxi-
28 mately with previous runs performed under similar conditions but
29 without kerosene vapors in the gas stream. No visible carbon deposi-
30 tion was observed in the catalyst after the run. The fines obtained

1 amounted to approximately 0.5% per weight of total catalyst and it is
2 to be noted that this amount of fines is usually obtained after each
3 run. From this data it can be seen that kerosene vapors do not effect
4 the activity of the present catalyst.

5 The effect of steaming on the catalyst of the present inven-
6 tion was investigated under the following conditions: The catalyst
7 used was an aged catalyst as described above; the space velocity (STP)
8 was 700/hr; the steam to gas ratio was 1:1; the reactor pressures
9 were 0, 22 and 100 psig; and the feed gas had the approximate
10 composition of 55% hydrogen, 25% nitrogen, 10% carbon monoxide and
11 10% carbon dioxide. The reactor was packed with 550 cc. of aged
12 catalyst of the present invention and was reduced for a period of
13 approximately two hours at a temperature of about 450°C. with a
14 mixture of gas consisting of 35% carbon monoxide and 65% hydrogen at
15 a space velocity of 145/hr. and a steam to gas ratio of 10:1. The
16 reactor pressure was atmospheric. The catalyst was then aged for
17 16 hours at the same conditions except that the temperature was raised
18 to 625°C.

19 The feed gas mixture was then introduced at the conditions
20 described above and the percent of carbon monoxide conversion was
21 checked at 425°C. and atmospheric pressure. The catalyst was then
22 steamed for 30 minutes at the same temperature and the percent conver-
23 sion was rechecked after that period with the original feed gas
24 mixture. The same procedure was followed at pressures of 22 and 100
25 psig.

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1 In Table II is found a tabulation of the results obtained.

2 TABLE II

3	Pressure	Steaming	%CO	Time-hrs. When Sample Was	
4	<u>T°C.</u>	<u>Psig.</u>	<u>Period-Hrs</u>	<u>Conversion</u>	
				<u>Taken Following Steaming Per.</u>	
5	428	0	-	79.8	-
6	427	0	0.5	81.5	3.50
7	425	22	-	81.5	-
8	430	22	0.5	86.5	3.50
9	430	100	-	86.5	-
10	425	100	0.5	80.2	1.50

11 From the above data, it could be determined that no large
12 effect on the activity was observed.

13 The effect of acetylene on the catalyst of the present inven-
14 tion was investigated as follows. The conditions of the test were:
15 Aged catalyst was used; the space velocity was 770/hr; the steam to
16 gas ratio was 1.13:1; the reactor pressure was 100 psig; the feed gas
17 mixture had an approximate composition as follows: 50% hydrogen,
18 15-21% acetylene, 4-11% carbon dioxide, 20% carbon monoxide and 6%
19 methane; and the comparative gas mixture approximately contained 60%
20 hydrogen, 28% carbon monoxide, 6% carbon dioxide, 6% methane, 0.2%
21 acetylene and 0.2% oxygen.

22 The reactor was packed with 550 cc. of aged catalyst of the
23 present invention. At the beginning, the percent of carbon monoxide
24 conversion was checked at 425°C. with the comparative feed gas
25 mixture under the conditions described above. After this, the feed
26 gas mixture containing a high amount of acetylene was introduced for
27 one hour, maintaining the same pressure, the same steam to gas ratio
28 and the same temperature. Samples were taken after 15 and 45 minutes
29 and the temperatures were checked every 10 to 15 minutes. The percent
30 of carbon monoxide conversion was then rechecked with the original

1 mixture containing merely 0.2% acetylene. The gas mixture containing
 2 the high amount of acetylene was then introduced for an additional
 3 hour.

4 In Table III is set forth a tabulation of the results obtained.

5 TABLE III

6	Inlet	% C ₂ H ₂	% Unsat _s	% CO			
7	Gas %	in Exit	in Exit	in Exit			
7	T°C.	Comp.	Conv.	Gas	Gas	Remarks	
8	425	10.7-CO ₂ 14.9-C ₂ H ₂ 47 -H ₂ 17.8-CO 7.0-CH ₄	-	0.5	4.0	6.0	Sample taken 15 min. after introduction of gas mixture
9							
10							
11	425	Same as Above	-	0.5	3.7	3.7	Sample taken 45 min. after introduction of gas mixture
12							
13	425	Comparative Gas Mixture	81	-	0.2	5.4	
14							
15	425	3.7-CO ₂ 21.1-C ₂ H ₂ 49.2-H ₂ 18.8-CO 5.0-CH ₄	-	0.6	4.2	6.5	Sample taken 15 min. after introduction of gas mixture
16							
17							
18	425	Same as Above	-	0.6	3.8	6.6	Sample taken 45 min. after introduction of gas mixture
19							

20 From the above data, it may be concluded that the presence of 14.9%
 21 and 21.1% acetylene in the gas stream did not affect the activity of
 22 the catalyst of the present invention. It is to be noted that the
 23 acetylene decomposed upon contact with the catalyst, about 0.2% to
 24 about 0.6% remained unchanged, 3.5% to about 4.2% of unsaturates
 25 (probably ethylene, propylene, etc.) were formed, and an increase of
 26 methane was noted in the exit gas.

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1 Inasmuch as there is merely on the order of about 0.2% to
2 0.3% acetylene in the feed gas under normal conditions and up to
3 possibly 8-11% under abnormal conditions (such as when there is no
4 scrubbing), the use of feed mixtures containing such percentages of
5 acetylene was also investigated. As expected, the use of such lower
6 percentages also did not affect the activity of the catalyst.

7 The effect of hydrogen sulfide on the catalyst of the present
8 invention was investigated by a method involving the alternate feed-
9 ing of a 50% carbon monoxide - 50% hydrogen - sulfur-free gas mixture
10 and a gas mixture containing 0.6% hydrogen sulfide at a pressure of
11 350 psig. and at a temperature of 350°C.

12 450 cc. of the catalyst of the present invention were reduced
13 and aged by the usual procedure. The percent carbon monoxide conver-
14 sion was then checked using the aged catalyst with a sulfur-free gas
15 mixture consisting of 50% carbon monoxide and 50% hydrogen. The run
16 was performed at a pressure of 350 psig. and at a temperature of
17 350°C. The conditions were maintained at 770/hr., space velocity
18 (STP) and a steam to gas ratio of 1.5:1. The catalyst was then dumped
19 and the reactor was reduced for 12 hours with hydrogen at a temperature
20 of 500°C. and afterwards saturated for a period of three hours at a
21 temperature of 350°C. and a pressure of 350 psig. with a gas mixture
22 consisting of 99.4% nitrogen and 0.6% hydrogen sulfide.

23 The reactor was then repacked with the catalyst and the percent
24 carbon monoxide conversion was checked alternately with the sulfur-free
25 gas mixture and the one containing 0.6% hydrogen sulfide at 770/hr.
26 space velocity, 1.5:1 steam to gas ratio, 350°C. and a reactor
27 pressure of 350 psig. A tabulation of the results obtained in this
28 run are set forth in Table IV.

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TABLE IV

1					
2	Time-Hrs.	Temp. °C at	% H ₂ S in	% H ₂ S in	% CO
3	<u>From Start</u>	<u>Bottom of Bed</u>	<u>Inlet Gas</u>	<u>Exit Gas</u>	<u>Conv.</u>
4	0		None		
5	7.75	348	None		70.3
6	28.25	352	0.605	0.210	
7	30.25	352	0.605		73.3
8	34.25	346	0.605	0.230	
9	35.00	357	0.605		74.5
10	36.25		None		
11	40.50	348	None		71.1
12	44.75	350	None		71.9
13	51.25		0.54		
14	52.25		0.54	0.450	
15	53.75		0.54	0.174	
16	54.25	360	0.54		77.8
17	57.00		0.54	0.201	
18	58.00	350	0.54		67.0
19	59.50		None		
20	63.50	352	None		72.2
21	75.50	352	None		74.4

22 From the above data it can be concluded that the activity of the
 23 catalyst was not affected while operating under a pressure of 350
 24 psig. The percent carbon monoxide conversion was approximately
 25 72% ± 2% as compared to 70% when a sulfur-free gas mixture was used.

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1 The typical properties of the catalyst of the present inven-
 2 tion as compared to other catalysts now in use in industry are as
 3 follows:

TABLE V

I. CHEMICAL ANALYSIS (Ignited 1000°C. Basis)

	Weight %	Present Invention	Catalyst H	Catalyst G
7	L.O.I.	0.5	5.0	22.0
8	Fe ₂ O ₃	95.0	83.0	87.0
9	Cr ₂ O ₃	4.0	4.0	11.0
	SO ₃	0.2	0.3	0.2
	MgO	0.0	0.0	1.0

II. PHYSICAL PROPERTIESA. Pellet Size, Inches

12	Average Diameter	0.30	0.44	0.37
13	Average Length	0.33	0.25	0.30
	% Fines (minus 4 mesh ①)	2.00	1.00	1.00

B. Crush Strength, Lbs.

15	Initial, average	47.6	20	30 *
16	% under 10 lbs.	0	6	--
17	After usage, average	40.2	24	30 *
	After wetting with water for 6 hrs at room temp.	36.1	5	5

* Variable

C. Bulk Density ②, gm./cc.

18		1.30	1.13	1.40*
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D. Dustiness Characteristics

19		Non-Dusty	Dusty	Dusty
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III. CATALYTIC EFFICIENCYA. Initial Activity

22	% Conversion of CO to CO ₂ at Standard Condition A ③	92	81	86
24	Same, except 400°C. instead of 450°C.	89	75	80

B. Stability

26	% Conversion at Standard Condition A after accelerated aging ④	87	75	81
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IV. RESISTANCE TO POISONING (Sulfur Gases, Acetylene, Kerosene, etc.)

28		Good	Poor	Poor (acetylene)
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- 1 ① U. S. Sieve Serial (0.187" openings)
2 ② Fill pint can (3-11/16" x 3-5/16" diameter). Put on vibratory
3 jigsaw platform (1 min.). Adjust level to brim with no projecting
4 catalyst.
5 ③ 450°C., 2000 hrs. ⁻¹ space velocity, 2.2 steam:gas ratio, dry gas:
6 35% CO, 65% H₂; 90 cc. catalyst in 2" tube.
7 ④ Aged for 16 hours at 625°C. in flowing gas (35% CO, 65% H₂)
8 (SV = 200 hours ⁻¹) plus steam (SV=1370 hours ⁻¹)

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1 Although we have described but a few specific examples of
2 our inventive concept and several tests thereof, as well as the
3 chemical and physical characteristics of a particular sample thereof,
4 we consider the same not to be limited to the specific substances
5 mentioned therein but to include various other compounds of equivalent
6 constitution as set forth in the claims appended hereto. It is
7 understood, of course, that any suitable changes, modifications and
8 variations may be made without departing from the spirit and scope
9 of the invention.

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The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In a method of preparing catalytic material for the production of hydrogen and carbon dioxide by the reaction of carbon monoxide and water vapor, the steps of forming an intimate moistened mixture of from about 85% to about 97% of iron oxide and from about 0.5% to about 15% of a member of the group consisting of ammonium dichromate and ammonium chromate, said percentages being by weight, ignited basis, with the iron oxide being calculated as Fe_2O_3 and said member being calculated as Cr_2O_7 , based on the total weight of Fe_2O_3 and Cr_2O_7 present, and drying the mixture.

2. A method as defined in Claim 1 wherein from about 3% to about 7% of said member is present.

3. A catalyst composition as prepared by the method of Claim 1.

4. In a method of preparing a catalyst for the production of hydrogen and carbon dioxide by the reaction of carbon monoxide and water vapor, the steps of forming an intimate moistened mixture of from about 85% to about 97% of iron oxide and from about 0.5% to about 15% of a member of the group consisting of ammonium dichromate and ammonium chromate, said percentages being by weight, ignited basis, with the iron oxide being calculated as Fe_2O_3 and said member being calculated as Cr_2O_7 , based on the total weight of Fe_2O_3 and Cr_2O_7 present, shaping said mixture into a desired configuration and drying the shaped mixture.

5. A method as defined in Claim 4 wherein from about 3% to about 7% of said member is present.

6. A method as defined in Claim 4 wherein from about 0.1% to about 10% by weight of a water-insoluble lubricant is added to facilitate the shaping of said mixture.

7. A moldable mixture for use in the preparation of a catalyst for the reaction of carbon monoxide and water vapor comprising an intimate moistened mixture of from about 85% to about 97% of iron oxide and from about 0.5% to about 15% of a member of the group consisting of ammonium dichromate and ammonium chromate said percentages being by weight, ignited basis, with the iron oxide being calculated as Fe_2O_3 and said member being calculated as Cr_2O_7 , based on the total weight of Fe_2O_3 and Cr_2O_7 present.

8. A mixture as defined in claim 7 wherein from about 3% to about 7% of said member is present.

9. A mixture as defined in Claim 7 wherein from about 0.1% to about 10% by weight of a water-insoluble lubricant is added to facilitate the molding of said mixture.